CORPORATION OF MADRAS.

A

MADRAS CITY
MAIN DRAINAGE, 1913.
VOL. I. REPORT.

(FOR ESTIMATES, SEE VOL. II.)

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J. W. MADELEY, M. A.,
M. Inst. C. E., M. Am. Soc. C. E., Etc.,
Special Engineer, Corporation of Madras.

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CORPORATION OF MADRAS,
SPECIAL WORKS DEPARTMENT,
MADRAS, 10*th April*, 1913.

TO

THE PRESIDENT,
Corporation of Madras.

SIR,

I have the honor to submit herewith a report—accompanied by plans and estimates—containing a description of my proposals for the Main Drainage of the City of Madras. The report also contains suggested Drainage Clauses for the new Madras City Municipal Act and proposed Drainage Byelaws to be made under that Act.

Following my usual custom, I have endeavoured to write this report in such a manner that it may readily be understood by all those who are interested in the drainage of the city. To this end it is illustrated by some thirty plates which should make it possible to obtain a general idea of the scheme without referring the drawings. To obtain a detailed knowledge of the proposals it will be necessary to study the drawings closely.

I take this opportunity to state how greatly I am indebted to the whole of my staff for the assistance which they have given in the preparation of this report. Mr. Coats who on 22nd March left my department to take up the duties of Corporation Engineer has been actively employed on the scheme for the last eighteen months. During that time he never spared himself and latterly he has worked nearly every holiday in order that it might be completed by the time I wished. Though my special thanks are due to Mr. Coats for his work on the scheme itself, they are hardly less due to my other assistants—Mr. Houston, Mr. Newland, Mr. Cartledge and latterly Mr. Adlard. These gentlemen have also done work directly connected with this report, but they have been of even greater value in relieving me as far as possible of work connected with those sections of the department which are under their immediate charge.

The large water-works and drainage works now being carried out by my department have already involved the letting of 23 contracts on the water-works and 47 contracts on the drainage works or an aggregate of 70 contracts, besides a considerable amount of departmental work. The total value of work completed or in course of execution is some 80 lakhs of rupees. Much of it is difficult, and most of it is of a description quite new to Madras. New methods have been introduced, new specifications drawn up, and some 1 300 drawings

have been prepared. Madras conditions have been studied and designs prepared to suit them. Special apparatus has been devised to meet particular difficulties, elaborate and tedious experiments have been carried out to determine what use can be made of the existing sewers, pumps and pumping mains. Finally, a large number of minor works have been executed to remedy especially bad nuisances and to insure that the fullest possible benefit is obtained from the existing system.

With all this work in hand, it would have been quite impossible to prepare the present scheme within the time promised, unless my staff had given me every assistance in their power. This they have done and I am glad to have this opportunity of acknowledging my indebtedness to them. My thanks are due not only to the officers already mentioned, but also to the subordinate staff —draftsmen, surveyors and clerks—who have always worked cheerfully overtime and on holidays when called upon to do so. Finally, my thanks are due to Mr. Barker for reading through and assisting me to correct the proofs.

I have the honor to be,

Sir,

Your most obedient servant,

J. W. MADELEY, M. A., M. INST. C. E., M. AM. SOC. C. E., ETC.,

Special Engineer,

Corporation of Madras.

CHAPTER I.

INTRODUCTION.

1. Urgency of carrying out drainage work. 2. Present position as regards drainage. 3. Further remedial measures of little use. 4. Work proposed and its estimated cost. 5. Estimated cost of work. 6. Order of execution of work. 7. Points upon which orders are requested. 8. Arrangement of report.

Urgency of carrying out drainage work.

1. There can be no doubt in the mind of any one who knows the City of Madras that the drainage system is very imperfect and that the health of the city must be adversely affected by the insanitary conditions. In Chapter XIV of this report, it is shown that the death-rate of Madras has steadily increased decade by decade during the last 40 years, and it is unlikely that there will be any decrease until the sanitation of the city is improved.

As explained in Chapter III, the existing drainage system consists of open side drains, masonry drains and pipe drains. The open drains are insanitary, the masonry drains are leaky and defective, and the pipe drains are very inefficient and in their present state must be a menace to the inhabitants of the city.

Present position as regards drainage.

2. The present position as regards the drainage is undoubtedly very unsatisfactory. In general it may be said of the different districts that—

(*a*) In those parts of Mylapore, Triplicane, Chintadripet, Periamet, Purasawakum and Vepery, wherever sewers of the old type have been laid, silt and storm-water are freely admitted; the system is rapidly breaking down and requires immediate attention. Many of the sewers will have to be relaid, and all of them require to be furnished with proper means for excluding silt and stormwater and with adequate arrangements for flushing and ventilation.

(*b*) In the other parts of these districts where there are no sewers, and also in Tondiarpet, Rayapuram and many Paracherries, there are open drains, mostly in a shocking state of repair, and sometimes mere earth ditches, full of putrid liquid, which creeps away, in some cases into old masonry drains, but more often it soaks into the ground or finds its way into tanks. Many of the side drains themselves are nothing but elongated cess-pools, in which the sewage lies stagnant, evolving poisonous gas and forming a breeding place for disease transmitting flies.

(*c*) The pumps which raise the sewage at the five old pumping stations are unsuitable in type and insufficient in power. Arrangements for screening the sewage and freeing it from silt are non-existent.

(*d*) The main leading to the Grass Farm is altogether too small to take the sewage which is to be expected when the new water-supply has been introduced.

(*e*) Georgetown is provided with a good class of open drains which deliver into sewers, and these in turn discharge into Rayapuram Pumping Station. But the sewers are too small, hence a great deal of the sewage overflows into the Canal and into the "Main Drain" running north and south through the middle of Georgetown. The "Main Drain" itself thus acts as a sewer for which purpose it is most unsuited in shape, in materials of which it is constructed and in its very flat gradient. In consequence a large quantity of putrifying material is constantly generating large quantities of foul gas which contaminates the air of Georgetown.

Thus the drainage of most of the city is in a most unsatisfactory condition and is likely to become even worse if not remedied before the new water-supply is introduced.

To put the drainage of the city into a satisfactory state is a very serious problem. This report has been prepared to show how this problem can be solved.

Further remedial measures of little use.

3. Every European on coming to Madras for the first time is appalled by the insanitary conditions to be found in many of the poorer districts. "Can nothing be done to remedy this state of affairs?" is his natural question. The best answer is to take him round the city and let him see how universal is the insanitation due to want of drainage. He then appreciates that isolated action would be futile. The insanitary conditions which have been allowed to come into being during a period of many years, cannot be put right instantly.

Remedial measures have been carried out almost to their furthest limit, and the Corporation recognising this fact have passed orders that no more remedial measures are to be executed without special sanction. Nearly every such measure brings more sewage to the drainage system and increases the burden on pumps that are already unable to deal with the sewage that comes to them. Before any further remedial measures are carried out, new pumps are required, and new pipe lines must be provided to carry away the sewage to the Grass Farm or other point of disposal.

In brief a definite scheme of drainage is required which will be steadily pushed through to completion. It is hoped that the scheme now submitted will meet the requirements.

Work proposed and its estimated cost.

4. It is proposed to do away with side drains and with the old "masonry" drains for sewage carrying purposes in all thickly populated areas, to lay new underground drains where required, to furnish such of the old underground drains as are to be retained with the appliances necessary to make them efficient, and to construct new pumping stations.

As regards the old underground drains, the heroic way would be to remodel the entire drainage system on the lines laid down for new work in this report. There is, however, every reason to believe that good results can be obtained without such drastic treatment, provided suitable pumps of ample power are installed and adequate means are taken to exclude silt and storm-water from sewers. By the use of silt catchers, and separators and with adequate flushing, it may be confidently predicted that the existing sewers will give satisfactory service, and with silt pits and screening chambers and new pumps of ample power the present surcharging of the sewers will cease.

Estimated cost of work.

5. Full detailed estimates are given in Volume II of this report. The following is a general abstract of these estimates:—

Description.	Amount.		
	RS.	A.	P.
Drainage of Mylapore area	8,08,000	0	0
„ Ice House Road area	9,35,000	0	0
„ Edward Elliott's Road area	5,08,000	0	0
„ Napier Park area	11,62,000	0	0
„ Graem's Road „	7,93,000	0	0
„ Lang's Garden „	4,36,000	0	0
„ Purasavakam „	14,11,000	0	0
„ Law College „	5,21,000	0	0
„ Rayapuram „	14,18,000	0	0
Allowance for drainage of Tondiarpet North area	2,00,000	0	0
Gravitation mains, intercepting sewer, etc.	6,57,000	0	0
Pumping mains, branch mains, etc.	7,10,000	0	0
Open channel extensions	95,000	0	0
Sewage farm extensions and sewage distribution channels	1,72,400	0	0
Total...	98,26,400	0	0

The total of Rs. 98,26,400 includes the cost of all the main drainage works dealt with in this report with the exception of Septic Tanks which may eventually be required at the Sewage Farm and for the large sewer to be laid in the First Line Beach to intercept the Harbour overflows. The costs of these two works are—

	RS.
Septic Tanks	2,19,500
Harbour Overflow Intercepting Sewer... ...	85,360
Total ...	3,04,860

If these two works are added, the total estimated cost of works for which and estimates have been prepared, amounts to Rs. 1,01,31,260. This amount provides for supervision.

In preparing the estimates it has been assumed that the resolution of the Corporation with reference to house connections will be enforced. This Resolution lays down that in the case of new houses, the owner has to pay for the whole connection from the sewer to the house and for carrying out the house drainage work in accordance with the byelaws of the Corporation. There will presumably be no difficulty in enforcing this portion of the Resolution.

As regards the existing houses, the Corporation will lay, free of cost to the owner, the connection from the sewer to and including the traps and silt-catcher. The Commissioners have decided that the owner must pay for the

alteration of the house drainage and for connecting his house drainage to the silt-catcher or trap provided by the Corporation. For the whole of Madras these two works may be roughly estimated at—

	RS.
Alteration of house drainage	15,00,000
Connecting to silt-catcher or trap	2,40,000
Total ...	17,40,000

There is a possibility that the Corporation may have to pay for one or other of these two works. If so, the corresponding amount as given above should be added to the total of the estimates.

Order of execution of work.

6. Nearly all the work proposed in this report is urgent, but the staff available—both superior and subordinate—and the labour available—both skilled and unskilled—are altogether insufficient to enable all the work to be carried out simultaneously.

In Chapter VIII the order of urgency is discussed and the works there recommended to be carried out first and their estimated costs are as follows:—

		RS.	A.	P.			
Pursavakam Area.—Pumping Station ...		1,64,850	0	0			
Pumping Main ...		4,43,546	0	0			
Gravitation Main ...		33,900	0	0			
Intercepting Sewer ...		1,73,100	0	0			
Street Sewers ...		11,17,420	0	0			
		19,32,816	0	0			
Contingencies & Petty Supervision at 10% ...		1,93,184	0	0			
					21,26,000	0	0
Napier Park Area.—Pumping Station ...		3,05,010	0	0			
Pumping Main ...		19,115	8	0			
Gravitation Main ...		6,500	0	0			
		3,30,625	8	0			
Contingencies & Petty Supervision at 10% ...		33,374	8	0			
					3,64,000	0	0
Ice House Road Area. Pumping Station ..		2,19,910	0	0			
Pumping Main ...		6,100	13	0			
		2,26,010	13	0			
Contingencies Petty Supervision at 10% ...		22,989	3	0			
					2,49,000	0	0
Law College Area.—Street Sewers ...				...	5,21,000	0	0
Rayapuram Area.—Street Sewers ...				...	14,17,000	0	0
				Total ...	46,77,000	0	0

In addition street sewers are very urgently required in parts of Chintadripet, Triplicane and Kistnampet (the Napier Park and Ice House Road areas). These sewers would involve an additional expenditure of Rs. 15,00,000.

This work and the remaining work proposed can be carried out only as the staff and labour become available.

Points upon which orders are requested.

7. In addition to general orders on the technical aspects of the scheme which will be passed as a result of scrutiny by the Sanitary Board and the Sanitary Engineer to Government, special orders are requested on the following points :—

(1) The work which the Corporation desires to be undertaken first.

(2) The staff and plant which may be employed. This is dealt with in Chapter VIII.

(3) The Byelaws. First-class house drainage is now being extensively introduced into Madras and it is essential that the Corporation should possess a code of byelaws which will ensure good work.

Special attention is drawn to the desirability of giving to the executive the greatest amount of power and discretion as regards construction work that the Corporation and Government consider expedient, in order to enable rapid progress to be made. The work already executed has been continually hampered by rules which have been drafted for permanent establishments and which have been applied to the Special Works Department, though they are not suitable for the management of large works of construction with a temporary staff. That the progress made has not been less, is largely due to the energy of the President who has never hesitated to use his full powers to get the work done, when the necessity has been demonstrated to him; but the writer has felt that in many cases where the President has had to take special action to prevent delay of the work, this special action should not have been necessary.

Arrangement of report.

8. The report is divided into two volumes. Volume I is the report proper and consists chiefly of descriptive matter. It gives the principles and data on which the proposed system has been designed, the results of experiments which have been made to determine the most suitable methods of solving problems peculiar to Madras, and describes in outline the works proposed.

Volume II contains detailed estimates of the cost of the works, divided into the fourteen main headings that are given in paragraph 5 (*ante*).

Thirty plates are bound up in Volume I of the report to assist the reader to understand the descriptive matter.

Accompanying the report are 191 drawings bound in four books contained in two cases.

VOLUME I.

The order of treatment is clearly indicated by the chapter headings given in the following list :—

CHAPTER. I. Introduction.
" II. History of the Madras Underground Drainage System.
" III. Existing System and its Faults.
" IV. Remedial measures already carried out and new works completed and in course of construction.
" V. Physical features of Madras and general outline of proposed Drainage Scheme.
" VI. Principles governing design.
" VII. Description of works proposed.
" VIII. Execution of works—Order of execution—Staff and Plant.
" IX. Agency for carrying out House Drainage Work.
" X. Sewer Pipes, Manholes, Lampholes, Flushing and Ventilation
" XI. House Drainage and House Connections.
" XII. Latrines and Nightsoil Depôts.
" XIII. Population to be dealt with.
" XIV. Death-rate and Drainage.
" XV. Sewer Gradients—Velocities—Silt Transportation.
" XVI. Sewer Cleaning and Silt-catchers.
" XVII. Sewage Pumping Stations.
" XVIII. Existing Cast-iron Pumping Main.
" XIX. Surface Water Drainage of Madras.
" XX. Madras City Municipal Act.
" XXI. Drainage Byelaws.
" XXII. Appendices.

VOLUME II.

ESTIMATES.

(*a*) Detailed estimates for typical works included in detailed estimates.

(*b*) Detailed estimates for works included in scheme.

(*c*) Detailed estimates for various works not included in scheme.

A detailed list of contents, the headings of the plates, and of the drawings, etc., is given on pages

CHAPTER II.

HISTORY OF THE MADRAS UNDERGROUND DRAINAGE SYSTEM.

9. 1890, Committee appointed. 10. 1891, Secretary of State engages expert. 11. 1893, Mr. Cousins' Report. 12. 1894, Government decide that Mr. Cousins' scheme is too costly. 13. 1895, Corporation put forward a scheme. 14. 1897, Government approve Corporation scheme. 15. 1903, Corporation sanction increased estimates. 16. 1904, Government ask for explanation of increased estimates. 17. 1905, Sanitary Engineer instructed to report. 18. 1906, Government order stoppage of work. 19. 1907, Special Engineer appointed. 20. Principal works executed by Special Engineer.

Early History.

1890, Committee appointed.

9. The history of underground drainage for the City of Madras may be said to begin with the Madras Government Order No. 643, Public, dated the 16th September, 1890, which reads as follows:—

"*His Excellency the Governor in Council resolves to appoint a Committee consisting of:—President—Colonel Pennycuick, R. E., Chief Engineer and Secretary, Public Works Department. Members—Mr J. A. Jones, Sanitary Engineer, Dr. W. G. King, Acting Sanitary Commissioner, to consider the lines on which expenditure can be most advantageously incurred on the water-supply and drainage of the Town of Madras and to furnish, if possible, plans and estimates.*"

This Committee submitted its report on 26th November, 1890.

1891, Secretary of State engages expert.

10. There was some difference of opinion between the Members of the Committee, and it was decided that an expert should be brought out from England to report. On the 11th July, 1891, a telegram was sent to the Secretary of State as follows:—

"*Madras Government and Municipality, Madras City, contemplate treatment of water-supply; drainage; purification of Cooum. Government cannot sanction large expenditure till examination by ablest expert procurable. We request your Lordship will engage such expert for period of six months on suitable terms. Reason for undertaking schemes is supreme necessity for improving sanitation of City and reducing death-rate.*"

In compliance with the request contained in this telegram, Mr. Cousins was appointed by the Secretary of State to examine and report upon the means to be adopted for improving the water-supply and drainage of the City of Madras and the purification of the river Cooum.

1893, Mr. Cousins' Report.

11. Mr. Cousins' report was communicated to the Corporation of Madras in G. O. No. 1000 A. M., dated 2nd August, 1893. This order was placed before the Corporation on the 28th August, 1893, when it was resolved that the consideration of the report should be deferred until receipt of the remarks of Colonel Pennycuick, then Chief Engineer to the Government of Madras. Colonel Pennycuick's remarks were conveyed to the Corporation in G. O. No. 1651 M., dated 7th November, 1894. He generally approved of the scheme, but calculated that the cost including house connections would be 61 lakhs of rupees—an amount considerably in excess of Mr. Cousins' estimate.

1894, Government decide that Mr. Cousins' scheme is too costly.

12. On this Government passed the order "*that the time has not yet arrived when the Municipal Commission could, with confidence, be advised to incur the large expenditure which its adoption would entail. The Commissioners will accordingly be requested to consider with care and in detail the steps which should be taken to put the existing system of disposal of nightsoil and rubbish in the city upon a thoroughly satisfactory footing.*"

1895, Corporation put forward a scheme.

13. Two drainage schemes—put forward respectively by Mr. Ellis and Mr. Loane—were considered by the Commissioners, who after some discussion, at their Meeting held on 3rd March, 1896, appointed a Committee to investigate the question. The report of this Committee was submitted to Government by the then President of the Corporation with his letter, dated the 19th March, 1896.

1897, Government approve Corporation scheme.

14. Government in G. O. No. 209 M., dated 12th February, 1897, "*approved the scheme for the drainage of Madras now proposed by the Commissioners which excluding the subsidiary project for Mylapore, is estimated to cost Rs.* 28,81,000.

The same G. O. also sanctioned the proposal of the Commissioners to undertake at once the drainage of Mylapore at a total cost of Rs. 3,50,000. These estimates amounting to about 32 lakhs of rupees appear to have been framed without going into detail, but the work was proceeded with.

1903, Corporation sanction increased estimates.

15. At their Meeting held on 26th January, 1903, the Corporation considered a Memorandum prepared by the President on the new drainage works. In the official proceedings of this Meeting, the President is reported to have said that the estimates at that time amounted to Rs. 48·65 lakhs. At this meeting, the Corporation resolved "*that pending the submission of the abstract of detailed estimates for each section of the city with the President's remarks thereon, the consideration of the drainage question on the President's Memorandum, dated 6th December,* 1902, *be deferred.*"

On 29th May, 1903, the Corporation again considered the revised estimates amounting to Rs. 48·65 lakhs and resolved "*that the detailed estimates as now submitted be sanctioned with the hope that the amount now provided will not be exceeded..... .....*"

In the printed Proceedings of the Meeting, the President is reported to have said "*that the estimates had been prepared in detail. Hitherto we have been dealing with lump sums.*"

16. In Memorandum No. 1349, dated 21st November, 1904, Government addressed the President asking him to state why the sanction of Government was not obtained for the revised estimate of Rs. 48·65 lakhs and requesting him to explain fully the cause of the large increase.

1904, Government ask for explanation of increased estimates.

On 28th November, 1904, the President in reply to this Memorandum addressed Government enclosing the Municipal Engineer's report on the revised estimates, dated 11th May, 1903, and on 27th January, 1905, the President in compliance with Government Memorandum No. 1584, dated 23rd December, 1904, submitted detailed plans and estimates.

In the course of his letter, the President remarked "*it will be seen that by far the largest single cause of excess is Mr. Cousins' under estimates of the length of sewers required.*"

From the President's statements quoted above, it is obvious that no detailed estimates had been prepared for the sanctioned scheme which was estimated to cost 32 lakhs of rupees.

17. In G. O. No. 1392 M., dated 11th July, 1905, the Sanitary Engineer to Government was "*requested to revise at a very early date in consultation with the President and the Engineer of the Corporation, the plans and estimates for the new drainage scheme, so as to make it as adequate and efficient for present and future requirements as circumstances will permit.*"

1905, Sanitary Engineer instructed to report.

18. In G. O. No. 1671 M., dated 17th September, 1906, was published the Sanitary Engineer's report in which he stated that the whole of the underground drainage work would have to be reconstructed after redesign, and that the sections where underground drainage work had not been started should be redesigned. The Government Order on this report states :—

1906, Government order stoppage of work.

"*In view of the defects brought to light by the Sanitary Engineer in the design of the works in progress, the Government agree with him in considering that further expenditure on the work on present lines should be stopped. The President will be requested to consult the Sanitary Engineer before he employs the staff further on the completion of the works already begun.*

"*The President is requested to call upon the Engineer, Madras Corporation, to submit, in consultation with the Sanitary Engineer to Government, detailed plans and estimates for the above works for professional scrutiny and sanction in the Public Works Department and to take up at once, in consultation with the Sanitary Engineer to Government, the preparation of detailed estimates for the drainage of the Tondiarpet Section on the lines suggested by that officer. The redesign and reconstruction of the drainage system in the five sections in which the works have already been nearly completed should be taken up after the estimates for the Tondiarpet Section are approved.*"

The Corporation considered the new position that arose through this Government Order and at their Meeting held on 3rd December, 1906, passed the following resolution :—

"*The Corporation in recording the Government Order places on record their opinion that before spending any additional sums on reconstruction of the Madras Drainage Works further and more convincing evidence of the unsuit-*

ability of the present works than is afforded by the Sanitary Engineer's report is necessary. In the absence of such evidence the Corporation is of opinion that the works done in the old five sections need not be disturbed. The Corporation, however, sees no objection to postpone the continuance of the drainage works in those sections until after the Tondiarpet Section is redesigned."

1907, Special Engineer appointed.

19. Government in G. O. No. 609 M., dated 22nd March, 1907, communicated to the Corporation a note by the Chief Engineer, Public Works Department, on the subject of the agency which it was desirable to employ for the execution of the drainage and water-works, and intimated that, if the Corporation so desired, Government would be prepared to introduce a bill to enable it to employ a Special Engineer, the services of such a Special Engineer being retained until the new water-supply and drainage schemes were completed. This Government Order was considered by the Corporation at their Meeting held on 16th April, 1907, when the following resolution was passed:—

" That the Corporation accepts the plans and estimates for the improvement of the water-supply. It is further of opinion that it will be advisable to place its two new works of drainage and water-supply under an expert Special Engineer with extensive practical experience in these branches who will work under the Corporation till these works are complete. It does not, however, think it necessary or desirable that he should be in charge of the ordinary works of the Corporation."

In G. O. No. 1019 M., dated 13th May, 1907, Government accepted the proposal of the Corporation that a Special Engineer should be employed solely to carry out the new water and drainage works, and a Special Act, No. IV, dated 1907, was passed to enable the appointment to be made. Under its provisions the writer was selected for the post, and joined duty in Madras on December 11th, 1907.

At this point began what may be called the recent history of the underground drainage system.

Recent History.

Principal works executed by Special Engineer.

20. When on December 11th, 1907, the writer reached Madras he found that all construction work had been stopped and that the drainage staff, both indoor and outdoor, had been disbanded. Certain remedial measures had been proposed and were in course of development. These remedial measures, in so far as they appeared desirable, together with other important and urgently needed works were taken in hand. The necessary surveys were made and drawings and estimates prepared, and construction was proceeded with as soon as sanction was obtained. A brief description of these works is given in Chapter IV. It is sufficient here to mention that they comprise :—

(1) *Works sanctioned by G. O. No.* 1700 *M., dated* 14*th October*, 1908. The Law College and Rayapuram Pumping Stations and 16-inch cast-iron main required on account of the breakdown of the Georgetown Drainage System.

These works were completed at the end of 1911.

(2) *Works sanctioned by G. O. No.* 654 *M., dated* 18*th April,* 1910, including—

(*a*) A complete system for irrigating the Sewage Farm.

(*b*) A pumping station at the Sewage Farm.

(*c*) A number of works connected with the City Main Drainage.

(*d*) The complete sewering of the three Northern Divisions of the City, and three pumping stations required to deal with the sewage.

All these works are nearly completed, except the Farm Pumping Station which, however, is well in hand.

(3) A large number of *remedial measures* which may be divided into two classes—

(*a*) Measures required for the removal of local insanitary conditions in those areas where they are especially dangerous to health.

(*b*) Small works, which pending the completion of the General Scheme, will ensure the greatest benefit being obtained from the existing drainage systems.

A large number of these remedial measures have been carried out and the efficiency of the drainage system has thereby been greatly increased. The Corporation has laid down, however, that priority should be given to major water and drainage works, and at their Meeting held on 21st November, 1911, the Commissioners passed the following resolution :—

"*The Corporation requests the President to relieve the Special Engineer as far as possible of all works not embraced in the abovementioned works,*" i.e., the Main Waterworks, the Tondiarpet Drainage Works and the preparation of a comprehensive scheme for the drainage of the city, "*and to instruct the Special Engineer not to undertake such extra work except on the written order of the President.*"

Thus at the present time the drainage works in progress are the Main Drainage Works which have been sanctioned by Government, and such minor works as are from time to time considered necessary.

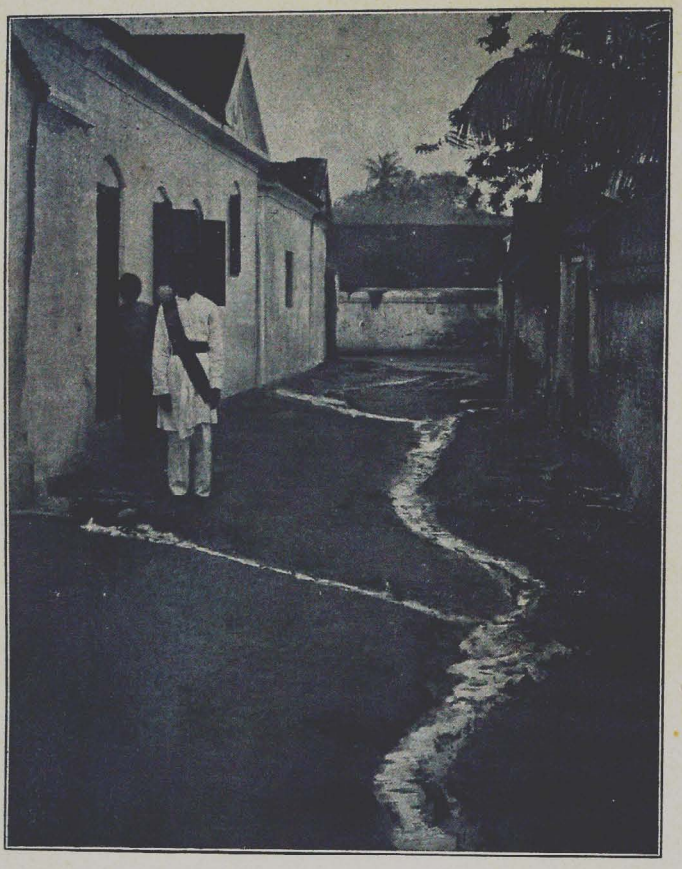
The Main Drainage Works now in hand are approaching completion, and the Special Works Department staff will be in a position to take up the construction of the new works proposed in this report as soon as they are sanctioned.

FAULTS OF EXISTING DRAINAGE.

PLATE I.

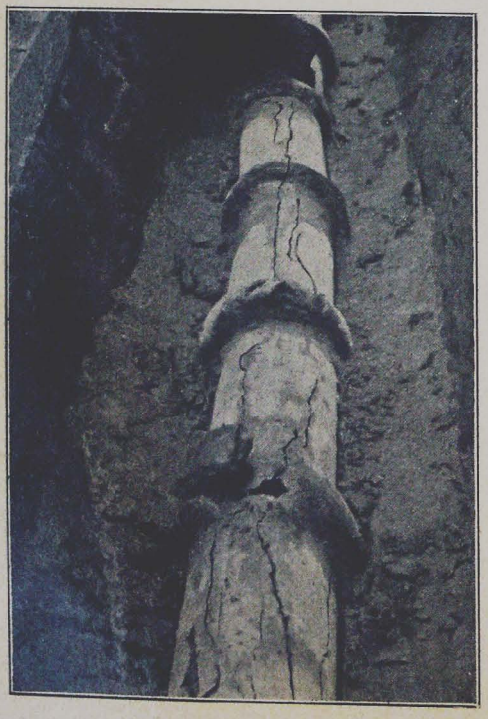
INSANITARY OPEN DRAIN.

Hundreds of equally insanitary drains exist in Madras.



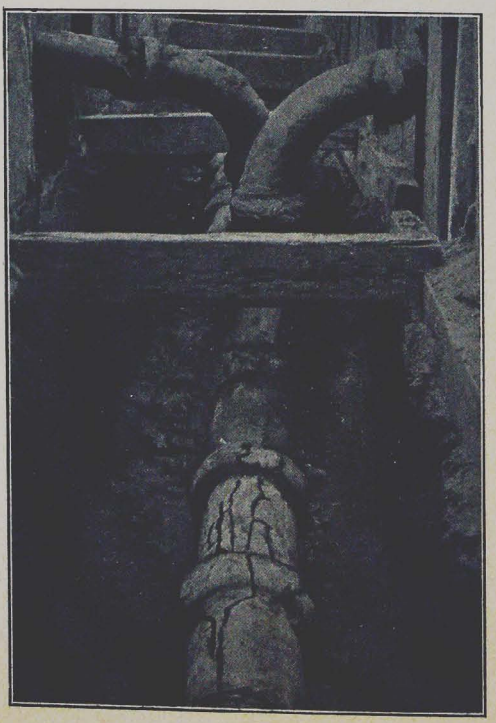
CRACKED CONCRETE PIPE.

Typical of many which will have to be replaced. Several sewers constructed with these pipes have already collapsed.



CRACKED CONCRETE PIPES AND FAULTY HOUSE CONNECTIONS.

Note house drains wrongly brought vertically downwards to connect on top of sewer.



Addison Press, Madras

15—A

CHAPTER III.

EXISTING SYSTEM AND ITS FAULTS.

21. Introduction. 22. Drainage areas. 23. Existing system.

Defects of Open Drains and Masonry Drains.—24. Evils of open side drains. 25. Foul gas generated. 26. Disease propagated by flies. 27. Open drains necessitate hand removal of excreta. 28. Silt, etc., carried into side drains. 29. Old masonry drains.

Defects of Existing Underground Drainage System.—30. Evolution of existing system. 31. Principal defects. 32. Free admission of silt. 33. Free admission of storm water. 34. Other defects. 35. Defective manholes. 36. Improper sewer junctions—Side drain connections. 37. Defective house drains. 38. Defects in house connections to sewers.

Defects of Existing Pumping Stations, Machinery and Mains.—39. Old plants inefficient. 40. Evil results from the absence of silt pits and screens. 41. Faults of existing cast-iron Pumping Main. 42. Summary of defects of existing sewerage system.

Introduction.

21. In order to understand what are the problems that have to be solved by the Drainage System now proposed, and in order to appreciate the importance of carrying out new works without delay, it is necessary to have some knowledge of the existing system and of the faults which have led to its condemnation. This section deals with these points.

Drainage areas.

22. For drainage purposes, Madras has been divided into a number of sections, each draining to a pumping station where the sewage is raised and sent along on its journey to the Sewage Farm at the northern boundary of the Municipal area.

Existing system.

23. The existing drainage system consists of a combination of open drains, masonry drains, and pipe sewers. All of these are intended to collect and convey to the pumping stations the "sullage" or soiled water which is discharged from the houses, but none of them perform their functions satisfactorily.

The open drains of Madras are insanitary. The masonry drains are leaky and defective. The old pumping stations are under-powered and are not furnished with any means of removing silt or floating rubbish from the incoming liquid. Indeed Madras affords an excellent example of the evils which result from a defective drainage system when applied to a large city. Some of these evils will now be described.

Defects of Open Drains and Masonry Drains.

Evils of open side drains.

24. The open drains in Madras are channels constructed generally along the two sides of the streets drained by them. In the first instance, these channels were doubtless earth ditches,—and sewage is still flowing in hundreds of earth ditches. An example may be seen by reference to Plate I which shows a reproduction of a photograph of an earth ditch conveying sullage. In later years the ditch has

generally been lined with masonry, usually of brickwork plastered with cement, and thus a channel has been formed, which, when in good condition, is impervious, and which is great improvement upon the original earth ditch. The disadvantages and dangers which attend the use of unrepaired, open drains in a populous town like Madras are well illustrated in those districts, where such drains exist. In many parts of the city—particularly in South Tondiarpet and Pursawaukam—are to be found networks of narrow roadways, each bounded on both sides by continuous earth ditches or delapidated brick drains full of liquid and semi-liquid putrifying sewage, which pollutes the air and gradually soaks away into the ground to foul the subsoil water. Clouds of flies rise off the stagnant liquid which, in some cases, may be seen to have soaked up the walls of the mud huts to a height of 2 or 3 feet above the ground. People are living in these huts with sewage soaked walls; and sewage lies before their doors and under their windows. It would be difficult to devise anything more insanitary or more detrimental to health.

Foul gas generated.

25. In Georgetown, a carefully thought out system of masonry side drains, delivering their sewage into underground sewers, has been installed. Here we see side drains laid as well as is possible in a flat city like Madras, but even here great faults are apparent. For many hours of the day, the side drains contain long lengths of semi-stagnant sewage, and the most familiar smell in the denser parts of this city is that of gas rising from putrifying sewage. Sewage gas itself has not been found normally to contain disease germs in greater numbers than does ordinary air, but it acts poisonously and insidiously, it lowers vitality, and renders those who breathe it unhealthy, and unable to resist disease. Sewage gas should be confined to its proper place and liberated well over-head, as will be done in the system of underground sewers now proposed.

Disease propagated by flies.

26. House flies may be observed any day in Madras to settle on the wetted sides of open drains, and to fly directly thence and alight on passers-by, on children's eyes, and on the food on the stalls of the bazaars. There may be washings, and urine and even fœcal matter in that sewage from a person suffering from enteric, tuberculosis, or cholera, and many diseases are known to be conveyed by flies. Nearly all exposed sewage in Madras may be seen to be the feeding or breeding place of countless mosquito-like flies and for this reason alone side drains should be abolished.

Open drains necessitate hand removal of excreta.

27. Another grave fault resulting from open drains is the necessity for hand removal of excreta, which, as carried out in Madras, is a filthy and degrading occupation employing a large amount of child and woman labour. Compared with the cleanly flush-out latrine and the water-closet, it is indeed a barbarism.

The importance of educating people to object to the sight and smell of sewage is great, for it gives them that "sanitary sense" which is so necessary if the full benefit is to be derived from sanitary measures. Side drains encourage insanitation; that is they make for dirt, smell and a high death-rate. All cities that have adopted good underground drainage, have shown a decrease in death-rate; the benefit has often been very immediate and marked.

Silt, etc., carried into side drains.

28. Every time it rains, large quantities of sand and road metal get washed into the side drains, which are also used as receptacles for much garbage and rubbish that should go direct to the incinerators. It is almost impossible to avoid frequent blockage of side drains, for it may take place only a few minutes after cleaning, and in consequence, a side drain, as a rule, contains long pools of more or less stagnant sewage.

The proper function of the side drains is the conveyance of rainwater, and for this purpose, it is proposed that they should be modified as was done in Bombay when underground sewers were introduced into that city.

Old masonry drains.

29. In the old days the side drains delivered the sewage into what were called "masonry drains," built of brickwork, approximately square in section and covered with granite stones. These masonry drains conveyed the sewage into larger "main drains" of a similar pattern, which in turn discharged their contents at one of the stations, where the sewage was raised on to the numerous farms then in existence. But in addition, a large proportion of the sewage flowed into the sea, or into the River Cooum, the canal, and various nullahs. Many of these masonry drains are still in use. They are most unsatisfactory as carriers of sewage; they are wrong in shape, they are nearly flat, and they are not water-tight. As a consequence, the sewage flows slowly, and its filthy silt is deposited to fill up the waterway and to give off noxious gases inimical to health. Further, the liquid escapes into the subsoil and pollutes the underground water which feeds the wells.

Defects of existing Underground Drainage System.

Evolution of existing system.

30. As already explained in Chapter II dealing with the history of the drainage, the existing underground system, as far as it has been carried out, was developed from a number of schemes proposed by various engineers and combined together by a Committee of the Corporation to form what they considered would be a satisfactory system. The system is full of faults of a technical nature about which the Commissioners could not be expected to possess expert knowledge.

Principal defects.

31. In the first place silt and storm-water are freely admitted into the sewers through house and side drain connections, and, secondly, the sewers are laid so flat that the liquid portion of the sewage cannot flow sufficiently fast to carry the heavy solid matter with it. Being far too flat to deal with even the best sewage, the daily addition of silt from every house drain and from numerous side drains has caused the inevitable breakdown of the existing sewers to come quickly.

Free admission of silt.

32. Silt should, as far as possible, be excluded from drains, sewers, and pumping stations. In Madras sewers it is now allowed to enter freely.

Plate VII shows the results of experiments on the "A B C main," which is the principal intercepting sewer in Triplicane, and is constructed of 15 inches and 21 inches diameter pipes.

As will be seen from the section, the Hydraulic Gradient line at 6 A. M. is the only one which is below the level of the sewer for any considerable distance. The Hydraulic Gradients at all other hours between 6 A.M. and 6 P.M. are well above the top of the sewer. This proves that between those hours the sewer was continuously surcharged, which means that ventilation was impossible, and that gas was compressed and forced up the house connections and through the traps.

The surface of the silt was measured and has been plotted on the diagrams from which it will be seen that the pipe is more than half full in the higher reaches and rather less in the lower reaches.

These experiments were carried out before systematic sewer cleaning had been introduced. From the levels in the pump well as shown on the left hand side of the diagram, it will be seen that there was backing up during nearly the whole of the day. The backing-up combined with the flat gradients is sufficient to account for the silting up. This sewer is typical of the larger old pipe sewers in Madras, and the results in other sewers are much the same. It is only by continual cleaning that the sewers can be kept in working order, while silt continues to be freely admitted.

Silt in quantity, always and quickly, stops up every form of trap—and traps are a necessity on every house drain. Silt in quantity inevitably puts flat sewers right out of action, daily menaces with stoppage even the best graded sewers, wears out their inverts, pours into the pumping station wells every time it rains, cuts and wears away the interior of the pumps, and commonly when there is a storm, buries the suctions and stops the pumps just when they are most required. It is therefore absolutely necessary to exclude silt from entering sewers in any but the smallest quantities.

Free admission of storm water.

33. Storm-water also should be excluded as far as possible from a sewerage system like that of Madras, which is designed to deal only with the "dry weather flow." If rainwater is freely admitted to such a system, the flow during the rains is multiplied many times, the sewers are unable to deal with it, the pumps are overpowered, the whole system becomes congested, and sewage entering the pipes at the higher points of each area overflows at the lower points through manholes, and house connections, and often finds its way into the houses themselves. This is what now occurs in Madras during heavy rain. At such times the sewers rapidly become surcharged and the pumps would make almost as much impression on the ocean as they do on the water that is brought to them through the numerous openings which freely admit storm-water. In fact the writer has seen the Napier Park pumps connected directly with the Bay of Bengal through the River Cooum, which was flowing to the pumping station so far as the open drains would take it.

Other defects.

34. These three faults—flat gradients, and the free admission of silt and storm-water are perhaps the principal causes of the failure of the old underground drainage system. There are, however, many other serious defects. The pumps are not sufficiently powerful, and the pumping mains are far too small to deal with the sewage. Arrangements at the pumping stations for

screening the sewage and freeing it from silt are nonexistent. The house connections are unsatisfactory, for they are continually becoming blocked, and they freely admit silt into the sewers. Arrangements for flushing the sewers have not been provided, except only in Mylapore, where owing to the searcity of water they are never utilised. Concrete pipes have been largely used, and investigation shows that many of them are on the point of actual collapse. A reproduction of a photograph of a pipe line of cracked cement pipes is given on Plate I.

Defective manholes.

35. Many details of the sewers are utterly wrong. No proper manholes were originally provided. Shafts were certainly built up, but some two feet below the road surface, they were completely covered with granite slabs on the top of which earth and road metal were placed. Not only was there no means of access to the shafts, but their very position was unknown. Furthermore, the manholes are unprovided with inverts. In consequence they form cisterns in which is deposited filthy silt which gives off poisonous gases.

Improper sewer junctions—Side drain connections.

36. The branch sewers have in many cases been connected to the main sewers by laying a pipe at a high level into the main sewer manhole. The sewage brought by the high level pipe falls vertically splashing the sides of the manhole and liberating noxious gas and harmful bacteria, besides retarding the flow which it would assist if the connection were properly made.

The side drain connections to sewers are of an exceedingly bad description. Not only do they freely admit silt and storm-water into the sewers, but they are untrapped and allow large volumes of sewer gas to foul the air at ground level.

Defective house drains.

37. The house drains are as full of faults as the sewers themselves. They are in fact small side drains which in their turn carry to the sewers large quantities of silt and storm-water. The silt quickly fills the siphon trap and is then forced into the sewer. The traps require to be cleaned at least once and in some cases even twice daily. The material is not collected immediately it is taken out of the siphon, but is placed on the road side where it is not only unsightly and emits smell, but what is much worse, the foul silt dries up and turns into an offensive and dangerous dust which is blown about and enters the eyes, mouth and lungs of the passers-by. It also penetrates the houses and settles on the food. A further serious defect of house drainage is that no provision is made for receiving solid excreta. The community is thus deprived of what is perhaps the principal advantage of an underground water carriage system of drainage.

Defects in house connections to sewers.

38. The house drains are in many cases improperly connected to the sewers. With the house drainage in its present condition there should be some means of intercepting the silt and removing it rapidly. In many cases the house connections are brought down vertically on to the top of the sewers (see Plate II.) thus causing a check in the flow and a deposit of solid matter in the latter. In no case are they provided with cleaning arms, and when they become blocked, as frequently happens with the surcharged sewers of Madras,

then it is necessary to dig up the road, break the pipes, remove the blockage and insert new pipes. These operations involve considerable cost in providing new pipes, in excavation, watching, lighting, and restoring the road surface. Furthermore, it is seldom possible to make a perfectly satisfactory job of such a repair, and however carefully the road is restored, the trench produces a most undesirable irregularity in the surface.

Defects of existing Pumping Stations, Pumping Machinery and Pumping Mains.

ld plants ficient.

39. There are five old sewage pumping stations which are known as Mylapore, Ice House Road, Napier Park, Lang's Garden and DeMellow's Road. To these stations respectively drains the sewage from the areas of Mylapore, Triplicane, Egmore, Vepery and Purasawakam. The stations are unprovided with silt pits and screening chambers. The pumps and engines are all very inefficient, and in the case of the steam plants at Ice House Road, Napier Park and Lang's Garden, they are all of an antiquated type. In any case it will be necessary to replace some of these plants which have been working for as many years as can be expected of machinery of this description.

Evil results from the absence of silt pits and screens.

40. In consequence of the complete absence of any arrangements for removing silt, and for freeing the sewage of floating materials such as leaves, cocoanuts and the like, there is a constant and rapid accumulation of deposit in the suction wells. This eventually closes up the suctions and makes it necessary to employ continually a gang of divers who in order to remove the silt, have to work submerged in sewage, an exceedingly filthy, and indeed a dangerous operation. A considerable quantity of silt and floating material is not deposited in the pump wells but is drawn into the pumps. The silt serves to grind away the surfaces of the pump rods and plungers, while the leaves and other floating material choke the pumps and prevent their efficient working.

Faults of existing Cast-iron Pumping Main.

41. The existing cast-iron main is 9 miles long. It starts at Mylapore and ends at the Sewage Farm. This main was intended to convey to the Sewage Farm the whole of the sewage collected in the drained areas of Madras. For this purpose it is totally inadequate It appears to have been designed to carry sewage at a maximum rate of 16 gallons per head per day for the population of 1891. The writer is designing his mains of sufficient capacity to pump at the rate of 67 gallons per head per day for a population exceeding that of 1891 by 44 per cent. Thus the capacity of the pumping main is *six times less* than that which in the opinion of the writer ought to be provided to enable it to carry satisfactorily the sewage of the areas for which it was designed.

The main is also wholly unprovided with washouts and has altogether too few air-valves. The consequence is that silt collects in the depressions and air at the summits, and as a consequence the main has a capacity equal to only one-half its nominal carrying capacity. The main, and how best to utilize it, have been the subject of much thought and experiment. The matter is dealt with at some length in Chapter XVIII, but enough has been said here to show that it is totally inadequate to fulfil the purposes for which it was laid.

Summary of defects of existing sewerage system.

42. The main defects of the existing underground drainage system may be summarised as follows :—

(1) *House Drainage.*—Silt and storm-water are admitted in large quantities. No provision has been made for receiving solid excreta.

(2) *House drain connections* are in many cases improperly made to the sewers. They are unprovided with cleaning arms and frequently become blocked.

(3) *Sewers.*—The gradients are too flat. Except in one division no proper flushing arrangements are provided. In some places the concrete pipes used are in a collapsing condition. No proper manholes were originally provided. The connection of a high level sewer to a low level sewer is made with a vertical drop resulting in splashing and interference with the flow of sewage in the main sewer. In most cases the so-called manholes have flat floors without any invert. Insufficient ventilation is provided. In many cases the sewers are too small to carry the sewage of the areas that they drain.

(4) *Pumping Stations.*—All the pumping stations except those completed within the last two years are unprovided with silt pits or screening arrangements. The pumps and engines at all the old stations are very inefficient. Except in the two pumping stations completed within the last two years the pumps are unable to deal with the sewage which comes to them.

(5) *The cast-iron main* into which all the original pumps discharged is too small to deal with the sewage which would be pumped into it if the pumps were of sufficient power. It is unprovided with washouts and in its length of 9 miles has only two air-valves.

(6) *Sewage Farm.*—Until the recently-completed works were carried out the irrigation of the Sewage Farm was very unsatisfactory. The main distribution pipe was too small, and the minor distributing channels were unable to convey sewage to a considerable area of the Farm.

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CHAPTER IV.

REMEDIAL MEASURES ALREADY CARRIED OUT AND NEW WORKS COMPLETED OR IN COURSE OF CONSTRUCTION.

Remedial measures already carried out.—43. Introduction. 44. Alterations to sewers. 45. Raising manhole covers. 46. Sewer cleaning. 47. Statement of work done by Sewer Cleaning Staff. 48. Increase in capacity of pumping plant.

New Works completed or in course of construction.—49. New works executed. 50. New works required to deal with Georgetown drainage. 51. Law College Pumping Station. 52. 16-inch cast-iron main. 53. Rayapuram Pumping Station. 54. 36-inch cast-iron pumping main. 55. Tondiarpet sewerage. 56. Data on which sewers were designed. 57. Tondiarpet Pumping Stations A, B and C. 58. Particulars of pumps provided. 59. Open channel. 60. Sewage Farm Irrigation System. 61. Minor works not described. 62. Value of works executed.

Remedial measures already carried out.

Introduction

43. In the last section the existing Drainage System and its faults have been dealt with. In this section will be given a brief description of the remedial measures which have been carried out and of the new works which have been completed or are in course of execution.

As already stated, these defective works were condemned by the Sanitary Engineer to the Government of Madras, and on his advice the whole of the work was stopped and the drainage staff disbanded. The writer's first drainage work upon taking up his post as Special Engineer for the design and construction of the water-supply and drainage for the City of Madras, was to make such alterations to the existing works as would enable them to be utilised to the greatest possible advantage.

Alterations to sewers.

44. In many cases the sewers were found to have been laid in scattered units. There were some sewers without manholes, unconnected with any outlet and destitute of house connections. These were brought into the existing system by building the necessary manholes, making the house connections, and laying such lengths of sewer as were necessary to connect up with the system

In addition, new sewers were laid in those districts where the sanitary conditions were especially bad.

Old brick drains were being used to carry sewage for which they were unsuitable, where the building of a short length of sewer was all that was required to divert the sewage and leave the old drains to perform the function of storm-water overflows, for which they are suitable. All works of this description, whose object is to ensure that the fullest benefit possible should be obtained from the existing drainage system, were put in hand.

Raising manhole covers.

45. A gang of men was got together and the manholes throughout the city—2,201 in number—have been raised to road level and fitted with cast-iron covers.

In many cases the manholes were spaced too far apart, and a number of intermediate manholes have been constructed, where they were most urgently required for cleaning purposes. Up to date 109 such manholes have been constructed.

Sewer cleaning.

46. When the manholes had been constructed and covers fixed, it was found that the sewers had become choked owing to the exceedingly flat gradients at which the sewers had been laid, combined with the inefficient pumping power installed at most of the stations, and the free admission of silt and storm-water. Complaints of nuisance and insanitary conditions, caused by sewage overflowing into yards and over road surfaces, became numerous.

It was clear that the only method of keeping the defective sewerage system in fair working order was to clean the sewers systematically and continuously, if the breakdowns, which had already occurred in many parts of the city, were not to become universal. A special foreman was appointed and provided with a gang of men whose duties now are to clean the sewers regularly, to remove obstructions and generally to look after the upkeep of the underground system. Under this arrangement, sewer cleaning is carried out by a gang of coolies in each of the sections into which the city is divided for drainage purposes. Another gang in each section is employed in removing obstructions and on other urgent work. Each of the cleaning gangs work under a Superintendent and has an average strength of eight men consisting of a jointer and seven coolies. For emergency work there are four men under the divisional peon. The total number of sewer cleaning and emergency work coolies at present employed is 146.

Though this number is insufficient to keep the sewers free from deposit, nevertheless the benefit to the sewerage system has been most marked. In those districts—such as Periamet—where the system had failed, it has been placed in a workable condition, and is now maintained so as to cause no nuisance to the inhabitants. The consequence is that complaints from such districts have greatly diminished in number. One result of the sewer cleaning has been to confirm what has been said concerning side drain connections, *viz.*, that the free admission of storm-water carrying with it sand, stones, leaves, twigs and other solids, causes the sewers to be frequently obstructed in spite of regular cleaning.

47. Some idea of the work done by the Sewer Cleaning Staff may be gathered from the figures in the following table :— **Statement of work done by Sewer Cleaning Staff.**

Statement showing Sewer Cleaning Work done from 31st December, 1909, to 31st March, 1912.

Division.	Length of Sewer cleaned in feet.	Obstructions removed.		Total quantity of silt removed in cubic feet.
		Sewer.	Siphon trap.	
Sewer No. 1 }	33,055	1	...	24,918
„ „ 2 } Georgetown ...	92,221	9	13	22,515
„ „ 3 }	162,000	4	...	20,525
12th Division, Periamet ...	190,988	354	152	17,398
13th „ Egmore ...	68,781	497	200	18,966
15th „ Nungambakam ...	3,596	158	36	2,269
16th „ Chintadripet ...	88,184	728	386	15,697
17th „ North Triplicane ...	84,776	413	138	14,074
18th „ South „ ...	38,752	1,959	688	20,841
20th „ Mylapore ...	113,031	648	169	16,092
Grand Total ...	875,384	4,771	1,782	173,295

An examination of these figures shows how great is the amount of cleaning required and also how frequent are the sewer obstructions which average six per day. The number of siphon obstructions points to the need for better house connections such as are proposed in this report. The obstructions enumerated in the table were all serious blockages which required cutting-out pipes. Less important obstructions are not included, because the siphons are cleaned by the Health Department, and it was only when an obstruction occurred which defied the powers of the siphon coolies that the Special Works Department was called in. To remove the obstructions it is necessary to excavate a trench in the road, cut out the connection, replace it with new pipes, and refill the trench. Needless to say such operations are very damaging to the road surface, and further, the junction between the new and the old pipes is not likely to be good. The Special Works Department is continually introducing silt-pits and other means of preventing road metal, sandy clay and other materials from entering the sewers. By degrees these measures will decrease the amount of cleaning required. Another desirable measure is to arrange proper emptying places for the Health Department cesspool carts. These carts are filled with the contents of cesspools and at present are emptied down manholes. The liquid runs away and the leaves, stones, tins and other solids gradually pass into the sewer and form an obstruction. Apparatus is required which will allow the liquid to enter the sewers while retaining the solids. A design for the purpose is now under consideration.

48. In the Purasawakum area where the pumps were more inadequate than in any other section of the city, a temporary pumping station known as the Periamet Pumping Station has been installed inside People's Park. An Oil **Increase in capacity of pumping plant.**

Engine and Centrifugal Pump no longer required at Rayapuram station have been erected here The second set consisting of an Oil Engine and Centrifugal Pump which are now no longer required at the Rayapuram Station has been installed in an extension of the DeMellow's Road Station, with the assistance of these two extra pumps, the dry weather sewage flow of the Periamet, Vepery and Purasawakum area is dealt with fairly satisfactorily. At DeMellow's Road new pumps are now being fixed to replace the old worn-out pumps at present in use. Both the Periamet and DeMellow's Road Pumping Stations will be abandoned if the scheme now proposed is carried out.

New Works completed or in course of construction.

New works executed.

49. Although many of them are required for the main drainage of the city, the above works have been classified as remedial measures because they deal with the improvement of the system which was in existence when the writer came to Madras. In the following paragraphs, the new works which have been completed or which are in course of construction will be briefly dealt with. The situations of the major works are shown on Plate No III, from which it will be seen that they are all situated in the North of Madras. They consist of—

(1) Two new pumping stations for the Georgetown area which has a population of 142,000

(2) A pumping main to convey the Georgetown sewage to the North.

(3) Three pumping stations (A, B and C) to deal with the sewage of Tondiarpet, the northernmost part of the city.

(4) A complete system of sewers for the Tondiarpet area.

(5) A brick sewer to carry the combined drainage of Georgetown and Tondiarpet to the Sewage Farm.

(6) A new pumping station at the Sewage Farm.

(7) An open channel to distribute the sewage over the Farm.

(8) A complete system of irrigation for the Farm.

In addition a number of minor works have been carried out which cannot be shown on the plan. These include :—

(9) Improvements to existing pumping stations, *e.g.*, installing Venturi Meters, sewage level and pump pressure recorders at all stations.

(10) Construction of Nightsoil Depot at Kristnampet to deal with nightsoil South of Madras—Divisions 17 to 20.

(11) Drainage of public buildings, *e.g.*, Kalyani Hospital, Royapettah Hospital, and Municipal Buildings.

(12) Reconstruction of large untrapped connections which liberate large volumes of sewer gas at ground level.

(13) Drainage of paracherries.

(14) Erection of public latrines.

(15) Drainage of areas that were especially insanitary.

New works required to deal with Georgetown drainage.

50. Works Nos. 1 and 2 comprise a new pumping station at the South end of Georgetown, the alteration of the existing Rayapuram Station at the North of Georgetown, and the installation there of new pumping plant. And the laying of two pumping mains 16 inches and 36 inches diameter, respectively, having a total length of $2\frac{1}{2}$ miles.

These works were required for the drainage of the Georgetown section of Madras which had completely broken down. This area is drained by side drains which discharge into sewers and these in their turn convey the sullage to the Rayapuram Pumping Station at the Northern end of the area. The causes of the break down of the system were in the first instance the insufficient capacity of the pumps at Rayapuram to deal with the sewage which came to them, and secondly the inadequacy of the sewers to convey the sewage to the pumping stations. The consequence was overflow into the Buckingham Canal on the West, and the Harbour on the East, while in the centre the sewers overflowed into a large main drain which falling North and South from a central point discharged on to the foreshore at both ends. At the South it produced a nuisance commonly known as "Kelly's Scent Bottle" which affected the Government Secretariat in the Fort, and the mercantile community in the South-east of Georgetown. At the North end a similar nuisance was created which affected mainly the staff employed at Rayapuram Railway Station. To abolish these nuisances the works detailed in the following paragraphs (9—13) have been carried out.

Law College Pumping Station.

51. Law College Pumping Station has been erected opposite the Law College at the South of Georgetown to pump to the Sewage Farm all the sewage which previously flowed over the foreshore and produced Kelly's Nuisance.

Three pumping sets have been installed each capable of delivering 870 gallons of sewage per minute against a total head of 70 feet. These pumps are supplied with steam from two boilers each of which is capable of supplying sufficient steam to enable any two engines, working together, to pump at their maximum rate.

The pumping plants are the well-known Worthington Triple Expansion Direct Acting Pumping Engines. The boilers are of the tubular type manufactured by Messrs. Babcock and Wilcox. They are fitted with superheaters capable of giving 100 degrees of superheat above the temperature due to the pressure of the steam Each pumping set is capable of dealing with the average dry weather flow *plus* a small allowance for rain. Two sets working together will be able to deal with the maximum flow anticipated and the third set is reserved as standbye.

The station is provided with collecting well, screening chambers and silt pits and three pump wells; all sunk as wells, this being necessary on account of the large amount of water encountered within a few feet of ground surface. The station itself rests upon a monolithic slab of concrete reinforced with steel rails.

16-inch cast-iron main.

52. A 16-inch cast-iron main—6,960 feet long—has been laid to take the sewage raised by the new pumps at the Law College Station and to deliver it into the pumping main from Rayapuram Station.

Rayapuram Pumping Station.

53. At the old Rayapuram Pumping Station, two new Worthington Triple Expansion Direct Acting Pumping Engines have been installed in place of two oil engines which were quite incapable of dealing with the sewage that came to them. The two new pumps are each capable of delivering 4,000 gallons of sewage per minute against a total head of 50 feet including suction

head and friction. The pumps have been connected with two existing Babcock and Wilcox boilers, in such a manner that each boiler can be used for working either engine or both engines, at will, and so that any engine or boiler can be cleaned or repaired without interfering with the working of the other engines and boilers. The existing boilers have been thoroughly overhauled. They have been provided with superheaters, and a Green's Economiser has been fitted in a new brick chamber which has been constructed on a bye-pass to the existing flue. Provision has been made for an additional engine, which will be fixed at some future time, if required. At Rayapuram Station it was necessary to lower the floor of the building by 10 feet, and also to lower the bottom of each of the two pump wells by 5 feet. The floor was lowered in sections and concrete, re-inforced with steel rods, was used for the new floor. It was a piece of work requiring extreme care because the new floor went below the footings of the pumping station walls. It is, therefore, very satisfactory to record that no accident and no crack of any kind occurred and no stoppage of pumping was necessary. Similarly the lowering of the pump wells required great care because these wells are partly inside the main station building and the bottoms are 20 feet below floor level. In order to avoid damage, the sinking was done by means of cast-iron caissons provided with diaphragms furnished with doors that could be rapidly closed in case of a rush of water. It is satisfactory to record that this work also was done without accident or damage of any kind, although it had to be carried out in running sand under a head of 12 feet of water. By means of these two works, the lowering of the engine house floor and the deepening of the pump well—originally considered impossible without stopping all pumping for a considerable period—the cost of building a new station and the sinking of new pump wells has been saved.

36-inch cast-iron pumping main.

54. A 36-inch cast-iron rising main 3,900 feet long has been laid to convey the sewage pumped at the Law College and Rayapuram Stations to the summit chamber in Tondiarpet where it is joined by the Tondiarpet sewage.

The 36-inch pipes were obtained from the Sewage Farm where they had been laid to distribute the sewage. They were too small for this purpose and have been replaced by the open channel.

Tondiarpet sewerage.

55. Tondiarpet has, for drainage purposes, been divided into three areas, *viz.*, A, B and C, each to be drained to its own pumping station. A is the western, B the central, and C the eastern station.

On arrival at station A, the sewage draining to this station will be raised at once to the full height required, and will then flow by gravity along a 24-inch cast-iron main to the well of Pumping Station B. The sewage arriving at Station C will similarly be at once raised, and will then flow along an 18-inch gravitation main until it likewise reaches the wells at Station B.

On their way to B, the 24-inch iron pipe sewer from A and the 18-inch stoneware pipe sewer from C, will both be utilised as intercepting sewers: by this means, it has been possible to extend area B both east and west beyond its natural contour limits.

These two gravitation mains—utilised also as intercepting sewers—run at right angles to the contours, and become in consequence, the deepest sewers of

the whole system. But the depth is well repaid. Every gallon of sewage they collect in the sewers of B area is saved being pumped a second time.

For, at station, all the sewage of areas, A, B and C is to be raised and sent on its way by the open channel. The sewage of districts A and C will have been pumped twice, but that of B once only, when leaving station B, hence it is obviously an advantage to make area B as large as possible.

The sewage of area B will, of course, drain to its own station, and Pumping Station B is to raise the whole sewage of South Tondiarpet into a brick sewer, 2 feet 10 inches in diameter, which will convey the sewage from the pumping station to the bell-mouthed junction chamber in Mannarswami Kovil Street. Into this chamber will be discharged also, all the sewage from Georgetown which is pumped from the Rayapuram and Law College Stations. The combined sewage will then flow by gravity along the 4 feet 6 inches diameter brick sewer, until it reaches the large Farm Pumping Station which is to be built at the head of the open channel

56. The following table gives for the three areas A, B and C, the acreages, populations in 1901, estimated future populations and estimated quantities of sewage :— **Data on which sewers were designed.**

Area.	Designation of Area.			Total.
	A.	B.	C.	
Built up area in acres	127	259	153	539
Unbuilt up area in acres	133	65	20	218
Total area in acres ...	260	324	173	757

Population.	Designation of Area.			Total.
	A.	B.	C.	
Population as per census of 1901	15,316	31,233	18,451	65,000
Increase of population over built up area taken at 30 per cent.	4,594	9,370	5,536	19,500
Future population of unbuilt up areas taken as 120·6 per acre	16,040	7,839	2,412	26,291
Total population for which the sewers have been designed	35,950	48,442	26,399	110,791
QUANTITY OF SEWAGE—				
Ultimate maximum rate in gallons per minute of sewage flow to the stations, at 46·3 gallons per minute per 1,000 of population	1,665	2,243	1,222	5,130

The sewers for these areas have all been constructed in accordance with the principles set out in Chapter of this report. All the pipes have been laid except a few deep sewers and the 24-inch gravitation main from Pumping Station A to Pumping Station B which was only recently started owing to the necessity of waiting for the completion of the laying of the 36-inch pumping main from Rayapuram with the pipes taken up at the Sewage Farm. It was not until this was done that it became possible to take up the 24-inch main forming the old pumping main and relay it as a gravitation main from Station A to Station C.

Tondiarpet Pumping Stations A, B and C.

57. The three Pumping Stations A, B and C, required to deal with the drainage of Tondiarpet, are brick buildings each supplied with three sets of Oil Engines driving Centrifugal Pumps. One set is capable of dealing with the average flow, two sets with the maximum flow, the third set being standbye.

Particulars of pumps provided.

58. The following is a summary of the particulars of the engines and pumps which have been ordered and the erection of which is now approaching completion :—

	Pumping Station.		
	A.	B.	C.
Makers of Engine	The Campbell Gas Engine Co.		
Makers of Pumps	Messrs. Gwynnes.		
Total number of units, each consisting of one engine and one pump	3	3	3
Number of units for maximum work	2	2	2
Number of standbye units	1	1	1
Maximum pumping capacity of each unit in gallons per minute	500	2,100	600
Working head in feet	20	25	20
Size of pumps	5″	10″	6″
Efficiency for maximum $\frac{\text{Pump H. P}}{\text{Brake H. P. of Engine}}$	50%	60%	50%
Water pump horse power	3·3	15·8	4·0
B. H. P. to drive pump	6·6	26·7	8·0
B. H. P. of engine using kerosine which would be required to give above B. H. P. on crude oil	7·3	29·4	8·8
B. H. P. of engines ordered	9½	30	9½
Revolutions of engine per minute	280	220	280
Approximate number of revolutions per minute of pump when pumping maximum quantity	1,040	360	830
Guaranteed consumption of liquid fuel in pints per pump H. P. hour	1·4	1·1	1·3

Open Channel.

59. The Open Channel that has been constructed along the West side of the Sewage Farm begins at its southern end with a receiving chamber 5 feet × 12 feet × 4 feet 9 inches.

This is separated from a gauging chamber (19 feet × 12 feet × 4 feet 9 inches) by a baffle wall. The sewage is delivered into the Receiving Chamber by the two pumping mains, and passing through openings in the baffle wall, flows as a quiet stream through the gauging chamber and over a weir to the channel proper, which is 6 feet 6 inches wide and 3 feet deep with a dished invert. The channel has a fall of 1 in 1,000 from South to North. With a depth of $2\frac{1}{2}$ feet, the calculated flow is 26,500 gallons per minute with a velocity of 4·8 feet per second. At the southern end, the channel is 12 feet above ground level, and is carried on brick piers 2 feet thick and 10 feet 6 inches long resting on foundations of surki mortar concrete. The piers are connected by arches 9 inches thick, each having a span of 12 feet, a rise of 2 feet, and a width of 10 feet 6 inches. There are 146 of these arches.

Where the floor of the channel is at ground level or slightly above, it is supported on two parallel brick walls running under the channel side walls. The space between the walls is filled with rammed sand and covered with concrete reinforced with $\frac{1}{4}$ inch steel rods.

Twenty wooden sluices of simple design have been provided to liberate the sewage along the length of the channel. Each sluice works in a masonry groove and is made of teakwood stiffened with an iron handle which works through a slotted bar built into the masonry. This bar acts both as a guide and regulator for the handle, and at the same time makes it impossible for anyone to steal the door. An iron pin chained to the slotted bar will allow each sluice to be opened as desired so as to allow the required quantity of sewage to be discharged. On opening a sluice, the sewage flows down a masonry shoot formed on a pier end of the channel and passes into the irrigating system.

Sewage Farm Irrigation System.

60. The sewage from the channel is discharged into 18-inch concrete pipes laid at right angles to the channel in parallel lines 600 feet apart. These pipes are provided with manholes at every 200 feet from which sewage can be supplied either directly into open channels slightly above ground level running above and a few feet to the side of the 18-inch pipes, or by means of 9-inch underground pipes to similar open channels running parallel to the main 18-inch pipe and 200 feet on each side of it. From these open channels the sewage is turned over the surface of any part of the Farm. At the same time the arrangement of the distribution system allows mowing and other agricultural machines to be worked from side to side of the Farm (about 1,500 feet) without encountering any obstacle due to channels or other irrigation works.

The masonry channel terminates at the northern boundary of the Farm in an end which is provided with boards working in grooves; by this arrangement the channel is kept as full as desired, and when there is an excess of sewage, the boards are removed as required and the excess allowed to discharge into the sea.

Minor works not described.

61. The foregoing description relates to major works that have been executed and that will form part of the city Main Drainage System prepared by the writer and dealt with in this report.

The minor works need not be described here. Their main headings are given in paragraph 60 on the three following pages, and the expenditure on them, as well as on the major works, can be seen from the statement given in the following paragraph :—

Value of works executed.

62. The following statement gives a brief summary of the works dealt with in this section, the authority for their execution, the amount of the sanctioned estimates, and the expenditure to 31st March, 1913:—

Description of Work.	Estimated Cost.		*Value of Work executed to 31st March, 1913.		Position of Works on 31st March, 1913.
	Amount.	Total.	Amount.	Total.	
	Rs.	Rs.	Rs.	Rs.	
MADRAS MAIN DRAINAGE.					
Works sanctioned in G. O. No. 1700 M., dated 14th October, 1908.					
LAW COLLEGE AND RAYAPURAM PUMPING STATIONS.					
Buildings	51,427		51,030		Completed.
Machinery	2,91,525		2,47,515		
Alterations to Sewers and Pumping Mains ...	15,758		2,070		
		3,58,710		3,00,615	
Works sanctioned in G. O. No. 1488 M., dated 22nd July, 1907.					
Laying 16-inch C. I. Main Pipe from Law College Pumping Station to Rayapuram Pumping Station	69,000		45,335		Completed.
		69,000		45,335	
Works sanctioned in G. O. No. 654 M., dated 18th April, 1910, and Rs. 16,000 sanctioned by Corporation on 23rd April, 1912.					
Open Channel at Sewage Farm, New Road Bridges, Sluices, etc.	92,000		82,710		Completed.
Raising existing 36-inch C. I. Pipes at Sewage Farm and relaying with New Pipes as a rising main from Rayapuram Pumping Station to head of 4 ft. 6 ins. Sewer	43,400		42,320		Do.
Circular Brick Sewer 4 ft. 6 ins. and 5 ft. 6 ins. diameter in Soorianarayana Chetty Street ...	88,500		46,935		Nearly completed.
Sewage Farm Pumping Station Buildings, Sewers, Overflows, etc.	1,01,000		4,990		In progress.
Machinery	2,01,000				Contract for part let.
Laying 36-inch brick gravitation main to Farm Station	10,200		...		Not started.
Irrigation work at Sewage Farm	44,500		36,085		Completed.
		5,80,600		2,13,040	
Carried forward ...		10,08,310		5,58,990	

* The figures in this column are only approximate in the case of incomplete works.

Description of Work.	Estimated Cost.		*Value of Work executed to 31st March, 1913.		Position of Works on 31st March, 1913.
	Amount.	Total.	Amount.	Total.	
	Rs.	Rs.	Rs.	Rs.	
Brought forward ...		10,08,310		5,58,990	
TONDIARPET DRAINAGE.					
Works sanctioned in G. O. No. 654 M., dated 18th April, 1910, and Rs. 1,500 sanctioned by Standing Committee on 28th April, 1911.					
Stoneware Pipe Sewers...	4,33,030		2,39,180		Nearly completed.
Cast-iron Pipe Sewers	37,095		4,370		In progress.
Brick Sewers	6,360		4,115		Completed.
Manholes	83,000		58,650		Nearly completed.
General, *i.e.*, ventilating columns, timber left in trenches, flushing chambers and restoring road surfaces, etc.	67,645		15,460		In progress.
House connection to Sewers	1,24,000		43,910		Nearly completed.
Overflows (A, B and C)	5,505		146		In progress.
Pumping Stations including machinery, etc.—					
A	55,815				Erection nearly completed.
B	97,605		1,04,850		
C	57,415				
Acquisition of land	9,850		9,294		Completed.
Contingencies	95,180		66,110		
Stores purchased but not yet used	...		54,560		
		10,72,500		6,00,645	
MISCELLANEOUS WORKS.					
Estimates sanctioned by Standing Committee and Corporation from time to time and included in Budget Statements.					
Constructing flush-out latrine for Engine Drivers, etc., at Law College Pumping Station ...	1,300		520		Completed.
Laying Sewers as required	53,045		33,350		Do.
Fixing Venturi Meters for the Pumping Stations.	34,000		34,030		Do.
Raising Manholes and fitting covers ...	73,700		73,570		Do.
Carried forward ...	1,62,045	20,80,810	1,41,470	11,59,635	

* The figures in this column are only approximate in the case of incomplete works.

Description of Work.	Estimated Cost.		*Value of Work executed to 31st March, 1913.		Position of Works on 31st March, 1913.
	Amount.	Total.	Amount.	Total.	
	Rs.	Rs.	Rs.	Rs.	
Brought forward ...	1,62,045	20,80,810	1,41,470	11,59,635	
MISCELLANEOUS WORKS—(*continued*).					
Estimates sanctioned by Standing Committee and Corporation from time to time and included in Budget Statements—(*continued*).					
Extending Engine-house at DeMellow's Road Pumping Station including machinery ...	19,000		4,030		In progress.
Sewage Level and Pump Pressure Recorders ...	8,050		7,620		Completed.
Alterations to existing Pumping Stations, Mains, Silt Pits and Screening Chambers ...	23,000		8,610		Deferred.
Royapettah Hospital Drainage	20,535		19,742		Completed.
Kalyani Hospital Drainage	5,880		5,880		Do.
Kistnampet Nightsoil Depôt	12,615		10,310		Do.
Municipal Buildings Drainage	24,000		...		Design completed and tenders called for.
Covering Kelly's Drain	15,450		11,770		Completed.
Petty Works	21,000		9,070		
Constructing store shed for the use as Drainage Stores at Napier Park	4,000		1,695		Completed.
Stores purchased but not yet used... ...	...		18,190		
		3,15,575		2,38,387	
Design, Supervision and Testing, &c., included in estimated cost of works (to be allocated when works have been completed).					
Supplies and Services (Home charges) ...	...		22,920		
Supervision, Sundries, etc.	...		2,31,300		
				2,54,220	
Grand Total ...		23,96,385		16,52,242	

* The figures in this column are only approximate in the case of incomplete works.

CHAPTER V.

PHYSICAL FEATURES OF MADRAS AND GENERAL OUTLINE OF PROPOSED DRAINAGE SYSTEM.

63. Position and extent of Madras. 64. Single large intercepting sewer impracticable. 65. Drainage areas. Trial Holes. 66. Utilization of old drainage work. 67. Contours. 68. Natural drainage divisions. 69. Means by which sewage will be conveyed to Sewage Farm. 70. Area to be drained. 71. Arrangement of drainage areas, mains, etc. 72. Northern Division. 73. Western Division. 74. Southern Division. 75. Utilization of existing cast-iron main. 76. Extension of Sewage Farm. 77. Alternative methods of dealing with drainage—Sewage Farm to the South. 78. Sewage Farm to the North-west. 79. Areas already drained. 80. Areas not included in scheme.

Position and extent of Madras.

63. Before proceeding to describe the General Scheme, it will be well to give a brief description of the physical features which affect the drainage.

Madras city is situated on a level and low lying sandy plain on the West Coast of the Bay of Bengal. It is bounded on the South by the river Adyar and on the East by the sea. The boundaries on the North and West are marked by no special physical features. The area of 27 square miles included within the Municipal boundary is approximately 9 miles long with a width varying from about 2 miles at its northern and southern extremeties to about 4 miles at the centre

The subsoil consists of sand in a strip along the sea coast. In the remainder of the area it consists of layers of sand and clay or sand and clay mixed.

Through the sand large quantities of water percolate, and at all times of the year, water is encountered within a few feet of the ground surface These conditions make it impossible to lay sewers at any considerable depth except at very great expense.

Single large intercepting sewer impracticable.

64 The question of constructing a large deep intercepting sewer running right through Madras from South to North into which could gravitate the sewage from the different drainage areas was considered, but was discarded on account of the length of time that it would take to execute, its high cost, and the considerable difficulties that would be encountered. Such a sewer would be wholly below subsoil water level and the only method of constructing would be by tunnelling with the assistance of compressed air to exclude the water. This work is necessarily slow, and it is costly on account of the plant and the nature of construction, for it would have to be lined with cast-iron segments Very little tunnelling of this description has been done in India, and it would be necessary to employ European contractors with European foremen and this would increase the cost.

For these reasons it was considered that one large deep intercepting sewer would be impracticable in Madras, though in England it would probably be recommended. Even in that country where skilled labour is readily available

and the materials required are cheaper--a long intercepting sewer would be very costly, but the elimination of nearly all the pumping stations would result in so great a simplification of the system and reduction in cost of upkeep as to warrant a considerable capital expenditure.

Drainage areas.

65. Having decided that one large intercepting sewer was impracticable for Madras, the alternative of dividing the city into a number of drainage areas was adopted. These drainage areas are limited by the depths at which sewers can be laid, that is, by the nature of the ground and the quantity of water encountered.

Trial Holes (Drawings 3 to 5.)

Where deep sewers would enable the areas to be extended, trial holes were excavated. These trial holes were 10 feet square and by their means the nature of the ground was accurately determined and the quantity of water that would require pumping into trenches was estimated very closely.

The positions of these trial holes and the nature of the ground met with in excavating them are shown on Drawings Nos. 3 to 5.

The depth at which it is possible to lay sewers at a reasonable cost is determined largely by the nature of the soil and quantity of water encountered. The worst conditions are those resulting from a fine sand with a large quantity of water under considerable pressure. Here the water carries the sand up as soon as it is excavated, and below a certain depth it becomes almost impossible to lay pipes. If, with great labour, care and expense they are laid, the pipes are very likely to be lifted by the water and sand boiling up from the bottom of the trench.

As a result of experience it has been found that in water bearing sand such as that which forms the subsoil of Tondiarpet in the North, it is not practicable to go to a lower depth than four feet below mean sea level. In those areas where the subsoil is clay, or clay mixed with sand, the quantity of water is much less and in the proposed system sewers will be laid as much as eight feet below mean sea level, *i.e.*, some 14 feet below mean subsoil water level.

Utilization of old drainage work.

66. In preparing the general scheme, the areas were first roughly worked out, in order to utilise the old drains as far as possible. To take up all the old sewers would be not only a great expense, but it would also cause great inconvenience to the inhabitants of the areas already sewered. As the result of experience, confirmed by experiment, it was decided that the existing sewers might be utilized, provided means were taken to render them efficient, and the present scheme has been worked out to make the greatest possible use of existing sewers. This has somewhat hampered the design as it has made it necessary to adhere as much as possible to the old drainage divisions.

These areas have been modified, extended and decreased as found necessary, and new areas have been added where there is a need of drainage which cannot be met by the pumping stations in the existing areas.

Contours.

67. Before commencing actual design, a large amount of work was done in taking levels over the whole city from which contour plans were prepared. Advantage has been taken of what small differences in surface level do exist in selecting the best positions for pumping stations, the best routes for main sewers and the most economical and efficient lay-out for the sewer net work.

The contours of the whole city have been plotted on large scale plans which are too unwieldly to send with this report. Those revelant to the present proposals have been transferred to the sewer plans for each area (see Drawings Nos. 99, 106, 111, 119, 129, 135, 157 and 182). A few of the contours have also been plotted to a smaller scale on Drawing No. 1, from which has been prepared Plate No. III. On this plate the darkest colour indicates the highest ground and the different shades show ground the average height of which above sea level varies by 4 feet for adjacent shades. A glance at this plate shows that the whole area is very flat. In general it rises away from the sea towards the West but there is a wide flat ridge running down from the North through Tondiarpet and Georgetown to the Cooum. This ridge divides into two minor ridges in South Tondiarpet and these two smaller ridges run right through Georgetown. There are also two low ridges running from West to East, one—the highest—through Mylapore, and the other through South Triplicane.

Natural drainage divisions.

68. The natural boundaries of the drainage divisions are provided by the Buckingham Canal running from North to South through the area, the Cooum River running from West to East through the centre of Madras, and to a minor extent by the Madras and Southern Mahratta Railway which divides Georgetown from Tondiarpet. By these divisions, the city is divided into three main drainage areas—the Northern, Western and Southern Divisions—as shown on Plate IV.

The *Northern Division* (coloured red) extends to the Municipal boundary on the North. It is bounded on the East by the sea, on the South by the River Cooum and on the West by the Buckingham Canal.

The *Western Division* (coloured blue) is bounded on the North and West by the Municipal boundary, on the East by the Buckingham Canal and on the South by the River Cooum, though, owing to the previously-existing drainage, it has been found necessary to extend this division to include part of the Southern Division.

The *Southern Division* (coloured yellow) is bounded on the North by the River Cooum, on the East by the sea, on the South by the Adyar and on the West by the Municipal boundary, though for the reasons already stated, a portion of this area has been included in the Western Division.

The three main drainage divisions are practically independent of each other, and within certain limits the work of draining any one of them may be carried without affecting the scheme for the drainage of the other two. The drainage of each of these three main divisions is sub-divided into separate drainage areas each commanded by a pumping station.

The following table shows this sub-division—see Plate VI :—

Northern Division.

Tondiarpet, North, draining to		Pumping Station	"D."
Do. South, A.	do.	do.	"A."
Do. do. B.	do.	do.	"B."
Do. do. C.	do.	do.	"C."
Georgetown, North	do.	Rayapuram Pumping Station	
Do. South The Fort	do.	Law College	do

Western Division.

Purasawakam Vepery	draining to Purasawakam Pumping Station.		
Egmore	do.	Lang's Garden	do.
Nungambakum	do.	Graeme's Road	do.

Southern Division.

Chintadripet and North Triplicane	draining to Napier Park Pumping Station.		
South Triplicane and Kistnampet	do.	Ice House Road	do.
Mylapore	do.	Mylapore	do.
Royapettah and [illegible]ampet	do.	Edward Elliott's Road Pumping Station.	

Means by which sewage will be conveyed to Sewage Farm.

69. The sewage from each of these three main drainage divisions is conveyed to the Sewage Farm by means of a separate channel. The Northern Division (shown in red, Plate IV.) by means of cast-iron rising mains, and gravitation mains of brick, stoneware pipes and cast-iron pipes. These mains have been in course of construction during the last three years and are now practically complete.

The Western Division sewage is shown to be conveyed to the Grass Farm by means of pumping and gravitation mains which are proposed for the first time in this report.

The Southern Division will be served by the existing cast-iron main. The lines of these mains are shown on Plate IV. The Northern Division mains by a thick dark red line; the Western Division mains by a thick dark blue line; and the Southern Division mains by a thick yellow line.

Area to be drained (Plate VI).

70. The total area for which the scheme provides and for which the cost is included in the estimates is fifteen square miles. A reference to Plate VI will show clearly and exactly what are the areas to be sewered. The cost of this work and of the remedial measures to bring the old drains into a satisfactory condition are provided for in the scheme now put forward.

Referring to Plate VI the areas proposed to be drained are hatched red. In these areas a drain will be provided for practically every road except narrow lanes and certain paracherries, where side drains with specially-designed connections to the underground drains are proposed.

The areas cross hatched in red represent that portion of Tondiarpet, the drainage of which is now practically complete.

The areas hatched blue are already sewered, but only partially and imperfectly. Many additional drains have to be laid. A number of existing drains require relaying. In all the existing drains means for excluding storm water and silt have to be installed, and the house connections remodelled. All these works are provided for in the estimates.

The uncoloured areas on Plate VI are those which are not yet ripe for draining, in which it is not anticipated that drains will be required for many years to come.

Arrangement of Drainage Areas, Mains, etc. (Plate VII).

71. With this preliminary explanation, attention may be drawn to Plate VII which shows the General Scheme in outline. The proposed drainage areas are shown by different colours. The existing pumping stations which will have to be renewed are shown by black circles with red centres. The existing pumping station at DeMellow's Road which will be dispensed with is shown by a black circle intersected by a red cross. The new pumping stations already constructed or in course of construction are shown by red circles hatched black. The existing pumping main which is to be retained for the Southern Division is shown by a thick black line. The proposed new cast-iron pumping mains are shown in blue, and the proposed new gravitation mains in red, while the pumping mains and gravitation mains already constructed or in course of construction are shown in the same colours hatched with black lines. The Sewage Farm is shown in green, the Open Channel in dark green, that portion already constructed being hatched with black lines. From this plan it will be seen that the principal main drainage works are as set out in the following three paragraphs:—

Northern Division.

72. Law College Pumping Station discharging into a 16-inch cast-iron Pumping Main (No. 2) which enlarges into a 36-inch main on receiving the sewage from Royapuram Pumping Station and discharges into a Gravitation Main (No. 2) at the point where it is joined by the sewage raised at Pumping Stations A, B and C, Tondiarpet. The whole of the sewage of Georgetown and South Tondiarpet will flow down a 4 feet 6 inches brick Gravitation Main (No. 2) to a point close to the Sewage Farm where it will be joined by another 4 feet 6 inches brick Gravitation Main (No. 1) bringing in the sewage from Western and Southern areas. The whole of the sewage of Madras will flow from this point through a 5 feet 6 inches sewer to the Sewage Farm Pumping Station where it will be raised into the Open Channel.

Western Division.

73. The sewage from the Nungambakum area will drain to Graeme's Road Pumping Station and will there be pumped through a 12-inch cast-iron main (No. 4) to the margin of the Egmore area. Here it will enter the head of Gravitation Main (No. 4) leading to Lang's Gardens Pumping Station where it will be joined by the sewage from Egmore. At Lang's Gardens Pumping Station the combined sewage of the Nungambakum and Egmore areas will be raised and forced through a 21-inch cast-iron pipe forming Pumping Main (No. 3) to the head of the Purasawakum area. Here the combined sewage of Nungambakum and Egmore will be discharged into Gravitation Main No. 5 down which it will flow to the new Purasawakum Pumping Station close to Farren's Road. This main will receive a large proportion of the Purasawakum Sewage and will be gradually enlarged until it becomes a 3 feet 6 inches sewer on entering the station. At Purasawakum station the whole of the sewage from the Western area, including Nungambakum, Egmore and Purasawakum, will be raised and forced through a cast-iron main 36 inches and 33 inches in diameter (Pumping Main No. 6) to join the sewage from the Southern area on its way to the Sewage Farm.

Southern Division.

74. The sewage from Teynampet and Royapet areas will be raised at the proposed Edward Elliott's Road Pumping Station and forced through a short Pumping Main (No. 3) 12 inches in diameter to the Gravitation Main No. 3, which

will convey it to the Ice House Road Pumping Station. At this station the combined sewage of Teynampet, Royapet and South Triplicane will be forced into the Pumping Main No. 1, which will already be conveying the sewage from Mylapore. The whole of the sewage will then be pumped to Napier Park where it will be joined by the sewage from Chintadripet and North Triplicane. The whole of Southern Division sewage will be pumped through the existing cast-iron main (Pumping Main No. 1) to the head of Gravitation Main No. 1 in Tiruvottiyur High Road. Here it will be joined by the sewage from the Western area. The whole of the sewage from the Southern and Western divisions will then gravitate to the Sewage Farm, joining the Northern Division Gravitation Main No. 2 shortly before reaching the Farm Pumping Station.

Utilization of existing cast-iron main.

75. The existing cast-iron main which was designed to take the whole sewage of Madras will also be utilized to its fullest capacity in conveying to the Grass Farm the sewage from the Southern Drainage Division.

This main was originally intended to take to the Sewage Farm the sewage of the whole of Madras. For this purpose it is wholly inadequate.

In his scheme for the Drainage of Tondiarpet and interconnected Main Drainage work, the writer cut out Georgetown and Tondiarpet from this cast-iron main. These sections form the Northern Division. Even after cutting out Georgetown and Tondiarpet, the existing cast-iron main was found to be much too smal to carry the sewage of the remainder of the city without putting it under an altogether prohibitive pressure. After considering the question carefully, and after plotting a large number of hydraulic gradients, the writer decided to cut out also the Purasawakum, Egmore and Nungambakum areas. These in the new scheme form the new Western area. Thus the existing cast-iron main will be used for the Southern area only.

The necessity for cutting out the Western area is shown by the hydraulic gradients which have been plotted on Drawing Nos. 6 and 7 and Plate XX. In the bottom diagram of Plate XX the maximum hydraulic gradient for the cast-iron main, if used for both the Southern and Western Districts, is shown by a blue curve. From this it will be clearly seen that if an attempt was made to pump the Western area sewage in addition to Southern area sewage through the main, it would result in failure. The pressures would be so high that the pipes would most probably burst and the head would vary so much that pumps of an expensive type would be required, and even these would be extravagant in working.

If the Western area is cut out as proposed, we get the hydraulic gradient shown by the red curve marked " A." The pressure still remains excessive at the head of the main and it is therefore proposed to re-pump the sewage from South Triplicane, Teynampet and Mylapore, at the Napier Park Station. By this means, the hydraulic gradient is lowered from A-A to B-B and reasonable pressures are ensured.

Extension of Sewage Farm. (Drawings 69 to 81).

76. An extension of the Sewage Farm to the North is proposed in order to deal with the increased quantity of sewage which will drain to the system, owing firstly to the largely increased number of underground drains that will be

connected to it, and secondly to the larger volume of water that the new Water-works will bring into the city.

The present Sewage Farm deals with some five million gallons per day which is the total dry weather flow now draining to the existing pumping stations. This quantity of sewage is nearly as much as can be dealt with on the Farm during dry weather. During the monsoon rains, when the ground is saturated, the sewage is turned into the sea. Thus with a larger flow, an extension of the sewage farm is necessary, and an extension in a northerly direction is indicated because the ground to the North is porous and barren. Irrigated with sewage, it should become as fertile as the existing Farm, and should prove a source of revenue to the city. To convey the sewage to this extension, it is proposed to continue the existing Open Channel along the western margin. From experience with the present Farm it is not anticipated that there will be any difficulty in passing the sewage straight on to the land. Should, however, the introduction of a more complete Water Carriage System for solid excreta, make the sewage unsuitable for passing directly on to the land, then it may be treated in liquifying tanks, such as those shown in detail on Drawings Nos. 78 to 81.

The question of the healthiness or otherwise of the Farm need not be discussed here, for the Corporation has requested Government to appoint a Committee of experts to enquire into the matter. Their opinion should be authoritative, and if it is against the Sewage Farm, then some other method of dealing with the sewage will have to be considered. The simplest method would be to turn the sewage straight into the sea, though the construction of a suitable sea outfall on a coast which is being continually eaten away by the sea would be a difficult and costly operation.

Alternative methods of dealing with drainage—Sewage Farm to the South.

77. Before deciding upon the scheme described above, a number of alternatives were considered. Amongst these was sending the sewage from the Southern area to be dealt with at a new Farm to the South of Madras. This was abandoned for the following reasons :—

(1) South-east winds prevail in Madras for long periods in the year and a Sewage Farm to the South would be a nuisance to the residential districts which have been rapidly developed in that direction.

(2) If the Sewage Farm were situated so far South as not to be a nuisance, it would be necessary to have an expensive crossing of the Adyar River and to convey the sewage so far South that the distance to it from the centre of the Southern area would be no shorter than it is to the existing Farm in the North.

(3) A Farm in the South would require a separate establishment and additional supervision.

Sewage Farm to the North-west.

78. Another alternative considered was the establishment of a Farm to the North-west of Vyasarpady close to the Municipal boundary. A Farm in this position would have the advantage that the prevailing winds blow away from Madras, so that it would not be a nuisance to the city. Also from its position—some 3 miles inland—the danger of erosion would be eliminated. It was only

after prolonged consideration, that the proposal to establish a Farm at Vyasarpady was abandoned, the reasons being—

(1) That trial holes proved the soil to be of clayey nature so that a very large area would be required to deal with sewage. Whereas the land might be suitable for farming where the quantity of water available for irrigation was limited, it would not be suitable for the disposal of a large volume of sewage on a small area.

(2) That it would be difficult to dispose of the sewage in wet weather without causing some nuisance.

(3) That, as in the case of the Farm to the South of Madras, a Farm to the North-west would require a separate establishment with its accompanying expense.

Areas already drained.

79. Plate No. VI is a map of Madras showing the areas already sewered hatched in blue, and the areas that require sewering hatched in red. The Tondiarpet area in which sewering work is in progress is cross hatched in red.

The areas shown hatched in blue are however, only partially or incompletely sewered. Many of the sewers require relaying. Some of them have been laid with concrete pipes which are in a state of collapse (at the present time a concrete pipe sewer in Waller's Road, Chintadripet, is being taken up and re-laid with stoneware pipes by the Special Works Department). Nearly all the old house connections have to be altered so as to exclude silt and storm water, and the junctions of one sewer with another will, in many cases, have to be re-made. The areas to be drained are mostly drained by means of open drains already described. As a general rule they discharge into sewers running to one or other of the various pumping stations. Where sewers do not exist, they discharge into the Cooum, the canal, or into tanks, or over low lying ground.

Areas not included in scheme.

80. The areas left blank are not included in the present proposals for, unless unexpected developments take place, they are not likely to be ripe for sewering for many years. Should necessity arise, they can be dealt with as follows :—

The area to the West of Tondiarpet in the North, if made inhabitable, can be dealt with by means of a separate pumping station delivering into the Sewage Farm Open Channel.

The Perambur area including Sembiam can be brought into the main Western area by a pumping station which would deliver to the proposed new Purasawakum Pumping Station.

The drainage of the extreme West of Egmore and Kilpauk could be taken into the Western Division in the same manner or pumped to a separate small Sewage Farm or other disposal works outside the Western Municipal boundary.

The South-west Adyar area can be dealt with, possibly in conjunction with Saidapet, by means of a Sewage Farm close to the sea near Elliott's Beach.

The above are indications of methods by which the sewage of these areas may be dealt with, but the time when they will require drainage appears so remote that it would be useless at the present time to consider in detail how they shall be drained, as the conditions may be quite different when the drainage systems come to be laid out.

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CHAPTER VI.

PRINCIPLES GOVERNING DESIGN AND RULES FOR LAYING OUT DRAINAGE SYSTEM.

81. Principles governing design. 82. Rules followed in laying out drainage system. 83. Principles discussed in this chapter. 84. Underground drains *v.* open drains. 85. Comparative cost of underground and open drains. 86. Cost of draining Georgetown by open drains. Cost of draining Georgetown by underground sewers. 87. Comparative cost of maintenance of open and underground drainage systems. 88. Separate system. 89. Considerations governing choice of pumping station sites. 90. Objections to long pumping mains. 91. Advantages of gravitation mains. 92. Benefit of gravitation mains in the system now proposed. 93. Utilisation of existing sewers.

Principles governing design.

81. The following are the most important principles governing the design of the drainage system proposed in this report :—

(1) The closely built-up areas of the city will be drained throughout by *underground sewers*. In those areas where the population is very meagre and scattered, the present method of conservancy will be continued. In some cases local methods of disposal may be adopted, *e.g.*, application of sewage to land, incineration of nightsoil, and such other methods as the conditions may warrant. See paras. 84 to 87 below.

(2) That in the drainage system, *storm water will be excluded* as rigidly as possible. See paragraph 88 below. The special arrangements provided to exclude the storm water are dealt with more particularly in Chapter XI.

(3) That *silt will be excluded* from the sewers as far as possible, the special "Madras" apparatus being used where required. The effects of silt and the methods to be taken to secure its exclusion are dealt with in Chapters XV and XVI.

(4) That the *built-up portion of the city be divided into areas*, the drainage of each of which will gravitate to a pumping station, so situated as to deal with the largest possible area.

(5) The *existing drainage system will be utilised as far as practicable.*

(6) The *sewers will be laid at the flattest possible gradients* consistent with efficiency in order to extend the boundaries of the drainage areas as much as possible. The question of gradients is fully dealt with in Chapter XV.

(7) For the same reason, the *main sewers will be continued until the depth attained makes further laying impracticable.*

(8) *Ventilation will be provided by means of shafts and perforated manhole covers.* Where conditions render them necessary, special measures will be taken to secure adequate ventilation.

By *omitting the intercepting traps* on first-class house drainage connections as proposed in Byelaws Chapter XXI, a great assistance will be secured towards efficient ventilation of the sewers. A short discussion on ventilation will be found in Chapter X.

(9) *Flushing arrangements will be provided at the heads of all sewers* and at such other points as require flushing. The waste water from street fountains and washing places will be utilised, as far as possible, for flushing both latrines and sewers. Some notes on flushing will be found in Chapter X.

(10) Short pump deliveries and *gravitation mains* will be adopted as far as possible in preference to long pumping mains.

Rules followed in laying out drainage system.

82. The following rules have been followed in laying out the system :—

(1) The *sizes of sewers* in all cases have been fixed so as to be capable of carrying off in six hours half the whole daily quantity of sewage of the anticipated population of 1960 of the areas drained by them, *plus* an allowance for rainfall equal to one-third of the maximum flow. The pipe sewers will be half full and the brick gravitation mains three-quarters full, when carrying this flow.

Thus the maximum carrying capacity of the pipe sewers will be at least $5\frac{1}{3}$ the estimated average dry weather flow of 1960. While the brick gravitation mains will carry at least $3\frac{1}{2}$ times the same dry weather flow.

In some cases, where the nature of the district renders it desirable, the size of the sewers has been made somewhat larger than the above rules would give, so as to make their capacities sufficient for future development.

(2) The *mean dry weather* flow for the sewers is taken as 25 gallons per head per day for the anticipated population of 1960.

(3) The sewers have been laid out at gradients that which will give self-cleansing velocities: the ordinary limiting *gradients* are–

Diameter.	Ordinary Maximum Gradient.	Ordinary Minimum Gradient.
4-inch ...	1 in 20	... 1 in 40
6 „ ...	1 in 40	... 1 in 135
9 „ ...	1 in 60	... 1 in 230
12 „ ...	1 in 90	... 1 in 340
15 „ ...	1 in 130	.. 1 in 460
18 „ ...	1 in 160	... 1 in 580
21 „ ...	1 in 200	... 1 in 720
24 „ ...	1 in 230	... 1 in 860

The question of gradients is of very great importance. It has been most carefully considered, and is dealt with fully in Chapter XV.

The minimum gradients will be adopted only for those sewers—generally main sewers—where it is essential that the fall should be reduced to the minimum consistent with efficiency. All other sewers—by far the greater lengths—will be laid at steeper gradients up to the upper limit.

(4) For reasons of economy *brick sewers* will, as far as possible, be used for sewers that are too large for the employment of stoneware pipes. The main brick sewers have been designed of circular section, after carefully balancing the advantages of this section as compared with the oval section.

Cast-iron pipes will be laid as sewers in deep excavation where especially large volumes of water are encountered.

(5) *Rider sewers* will be employed wherever economy, safety or convenience can be secured by their use. For example rider sewers, connecting at manholes with the main sewer, can usually be profitably employed where such main sewer is of cast-iron or brickwork in deep excavation.

(6) All *manholes* will be provided with cast-iron covers. There will never be more than 300 feet between adjacent manholes.

(7) Special types of flush-out and dry *latrines* have been designed suitable for use by the different classes of the community. It is intended that these should be installed at convenient points all over the city. For description see Chapter XII.

(8) *Paracherries* will be drained by open drains connected to the sewers by connections furnished with specially designed silt and storm-water separators.

(9) *Night-soil depôts* will be provided for the introduction of night-soil into the sewers at suitable points, pending the complete installation of the water carriage system so arranged as to convey all night-soil rapidly to the sewers. See Chapter XII.

(10) At the *pumping stations* the plant will be sub-divided so as to be capable of dealing economically with the usual variations of flow. Stand-bye plant will also be provided. The number of units will depend on the quantity of sewage and the nature of the plant.

The *pumping plant* exclusive of the stand-bye will be capable of dealing with 3 times the estimated average dry weather flow of 1936.

(11) Where there is a considerable head or where the head varies greatly, direct acting Steam Engine Pumps will be employed. Centrifugal Pumps driven by Oil Engines, Suction Gas Engines or Electric Motors or pneumatic Ejectors or Humphrey Pumps will be employed where the lift is low and where the head is constant.

(12) All sewage, arriving at the stations, will be screened and deprived of silt before it reaches the pumps by special silt pits and screening chambers.

(13) House drainage will be so carried out as to prevent the introduction into the Municipal sewers of silt and storm water.

Principles discussed in this chapter.

83. A discussion of most of the more important of the above principles—so far as they admit of discussion—will be found in subsequent chapters of this report. A few remarks will be inserted here with reference to—

(1) the advantage of underground as compared with open drains,

(2) the desirability of a "separate" drainage system for Madras,

(3) the economical choice of pumping station sites,

(4) the advantages of gravitation mains as compared with long pumping mains, and

(5) the utilization of existing sewers.

Underground drains *v.* open drains.

84. Considerable doubt exists in the minds of some Indian gentlemen as to the advisability of underground drains. The writer is convinced that underground drains are far superior to open drains for a large flat city like Madras

In the case of underground drains, with the water carriage system, the filth resulting from human life processes is carried away very soon after deposit, and is removed from the inhabited areas before putrifaction has time to set in. The comparatively small amount of gas produced is liberated overhead at such a height that it is rapidly dispersed without causing any nuisance. Even with the old Madras underground sewers, the comparative cleanliness and freedom from foul odours in those areas, as compared with areas served by open drains, is most marked. Yet these sewers are very imperfect, and with a more perfect system the advantages will be still greater.

The faults of open drains are dealt with in Chapter III. Here it is sufficient to say that they carry the sewage so slowly that it has time to putrify before being carried away from the vicinity of human habitations, so that the most familiar smell in the denser parts of the city is that of gas rising from putrifying sewage. This gas lowers the vitality and renders those who breathe it unable to resist disease. The slow moving, and frequently stagnant sewage, affords feeding places for countless flies which carry the filth from the drains on to the food exposed to sale There may be germs of enteric, tuberculosis, or cholera in that filth, and thus the side drain may become the direct means of propogating disease. Not only are side drains insanitary, but they are unsightly and take up a considerable amount of the useful width of a street—a serious matter in the busy parts of a town which is becoming more and more crowded every year.

Furthermore, in a town like Madras, it is impossible to have a system of open drains only. The ground is so flat that it is necessary for the drain to be laid deeper and deeper as it proceeds so as to obtain sufficient fall to ensure a flow. A limit is thus soon reached when it is impracticable to go any deeper and then it becomes necessary to take the sewage into underground drains, so that in Madras an open drain system, pure and simple, is impossible. A good example of this is afforded by Georgetown. Although this area is one of the most favourable in Madras as regards the slope of the ground, nevertheless when the open drain system was worked out, it was found necessary to have underground drains along three sides and through the middle of the area. If the whole of Madras were drained on this system, it would still be necessary to have pumping stations and underground sewers. If the drains were to be efficient, it would be impracticable to have the drainage areas any larger than those provided in the scheme now submitted. That is to say, the number of pumping stations and the principal intercepting sewers would remain as now proposed.

Furthermore, the exclusion of silt and storm water from open drains present very difficult problems. In fact, time and time again it has been found necessary in Madras to cover over the " open " drains and thus convert them into imperfect closed underground drains.

Comparative cost of underground and open drains.

85. A prominent Indian Commissioner in discussing with the writer the comparative advantages of the underground and open drains systems in dealing with the sewage of Madras admitted that the underground system was more sanitary and better, but he was inclined to believe that it was too costly for this city, and that the open drains would be much less expensive. He based his conclusions upon estimates which have been prepared for underground and surface drainage systems in mofussil towns. It was pointed out to him that the conditions in most of the mofussil towns are very different from Madras in that the areas are much smaller, and that there is usually available for drainage purposes fall in one direction or other, such as does not exist in Madras. The Commissioner referred to then asked the writer to furnish him with a comparative statement of the cost of the drainage of open drains and closed drains for Georgetown. Georgetown is particularly suitable for the purpose, because in this area an open drain system has been actually carried out and an underground system has been closely estimated for. The pumping stations for both the systems are identical and may therefore be left out of account.

Cost of draining Georgetown by open drains.

86. The cost of the sewers and surface drains as actually constructed 10 02,685

Add 33 per cent. for increased cost of labour and materials 3,34,228

Cost of side drains and sewers at present rates ... 13,36,913

Add improved connections of side drains to sewers, storm water and silt separators, ventilators, and other works urgently required 1,50,000

Total... 14,86,913

Cost of draining Georgetown by underground sewers.

Sewers 6 inches to 36 inches in diameter 8 32,720

Manholes, etc 1,12,300

House connections, flushing tanks and ventilation .. 3,40,800

12,85,820

Add for contingencies 1,14,180

Total... 14,00,000

This shows that there is an estimated saving of Rs. 86,913 or slightly more than 6 per cent. in an underground system as compared with an open drain system for Georgetown. It may be confidently asserted that, as far as can be estimated, the initial cost of drainage by open drains with the necessary intercepting sewers would certainly not be less than the underground drainage system with house connections for which a sum of Rs. 30 per house has been included in the underground drainage system.

Comparative cost of maintenance of open and underground drainage systems.

87. In maintenance there would be a saving by the adoption underground sewers, due chiefly to the considerable expenditure now required for maintaining and cleaning side drains and for the removal of night-soil—

	RS.
From the figures furnished by the Health Officer, the nightsoil disposal for the Georgetown area is estimated to cost	32,500
Maintenance of side drains and their connections to sewers	40,000
Total...	72,500
The annual cost of the underground drainage system including flushing, cleaning drains and silt catchers may be taken as	15,000
Supervision	1,500
Total...	16,500

Thus a saving in maintenance will amount to Rs 56,000 per annum, but when the disposal of nightsoil by the Water Carriage System is adopted throughout Georgetown, there will be an additional saving of some Rs. 30,000 which is approximately the annual cost of private scavenging in Georgetown. Thus the underground drainage system is certainly not more expensive in first cost and is a great deal cheaper in maintenance. On the grounds of greatly improved sanitary conditions and reduced cost of maintenance, the underground drainage system is the only one which the writer would feel justified in recommending for Madras.

Separate system.

88. In the existing system storm water, though not provided for, is freely admitted. In the system now proposed, storm water will be excluded as rigidly as possible. The reasons in favour of adopting the separate system for Madras are as follows :—

(1) The cost is very much less, if the storm water is excluded.

In a city like Madras where all sewage has to be pumped, both the initial cost and the cost of working a combined system would be very much greater than that of a separate system, for the sewers would have to be designed to take a flow some thirty or forty times greater than the dry weather flow, and the pumps would have to raise a correspondingly increased quantity.

(2) The disposal works will have a much more uniform quantity to deal with in a separate system and can in consequence be made much smaller.

(3) The sewage is much more constant in character and is, therefore, more easily purified.

(4) The variation in flow being smaller, the sewers can be laid at flatter gradients, for it is the minimum flow that determines the grade of the sewers. Thus automatic flushing in dry weather is greatly reduced, and the quantity of water required is much less than in a combined system. This is an important point in Madras where water is scarce.

(5) With the smaller sewers required by the separate system sewers arrangements for ventilating are much simplified.

(6) The number of sewer connections is largely decreased, as no street gulleys are connected to them. This reduces the number of traps. It also removes the possibility of the nuisance which would be sure to arise through evaporation of the sealing water with consequent forming of untrapped openings through which large volumes of foul gas would escape at the level of the roads. To avoid this escape of foul gas during dry weather, it is commonly found necessary in the East to fill the gulleys during dry weather with sand, which has to be removed before the rains—involving a great deal of work which is likely to be performed imperfectly, with the result that sand is introduced into the sewers.

Considerations governing choice of pumping station sites.

89. The sites proposed for the pumping stations are largely determined by the decision to utilise the existing drainage system as much as possible. These systems have been laid out to fall in certain directions and these directions have in many cases had to be maintained for the main sewers. As far as possible the pumping stations have been so placed that the main sewers will all be approximately the same depth below ground level when they reach the station. The site has been chosen to be in or near the lowest lying part of the area, and in such a situation that it is not likely to cause any nuisance. The absolutely lowest lying land has, as a rule, not been taken for the reason that it is usually liable to flood.

In selecting a pumping station site, a tentative position has first been chosen from a study of the existing sewers and of the contour plan of the district. Trial calculations have then been made of the main intercepting sewers extending to the most distant parts of the area. A number of such trial calculations are necessary for each area. The best situation of the pumping station has only been determined in each case after a large number of trial and other calculations. The object has been to enable the pumping station to command as large an area as possible and to keep the net-work of sewers as shallow as possible, while maintaining efficient gradients throughout the system.

Objections to long pumping mains.

90. The principle of using gravitation mains has been adopted as far as possible in the new system in preference to long pumping mains for the following reasons :—

(1) Long pumping mains for sewage are very unsatisfactory on account of—

(*a*) the deposit of silt in low places,

(*b*) the accumulation of air in long lengths, and

(*c*) the great increase in pressure with the maximum discharge compared with the mean discharge.

The combination of these three factors very greatly diminishes the carrying capacity of the pumping mains.

The existing pumping main from Mylapore to Tondiarpet affords a good example of the extent to which a pumping main may silt up (see Chapter XVIII). The great variations in pressure in pumping into a longer closed rising main are shown clearly by the calculated pressure against which the pumps will have to work. These are given in Chapter VII from which it will be seen that in some cases the *maximum pressure is more than four times the mean pressure.*

Advantages of gravitation mains.

91. Gravitation mains have the following advantages :—

(1) By the use of gravitation mains, the area that can be drained to any pumping station is greatly increased, for the gravitation main acts as an intercepting sewer which, owing to the large volume of liquid flowing down it, can be laid at a flat gradient, and therefore can be carried a long distance before reaching a depth exceeding that at which economical construction is possible.

The enlargement of drainage areas, resulting from the use of gravitation mains, causes the number of pumping stations required to be greatly decreased. The pumps are larger and more efficient and the first cost and cost of upkeep are both much reduced.

(2) Short pumping mains discharging into large gravitation mains have the advantage of allowing a cheap class of pump to be used satisfactorily. For instance, Suction Gas or Semi-Diesel Oil Engines driving Centrifugal Pumps can be used economically with gravitation mains where there is a constant head to pump against. But in the case of a long pumping main where the head is varying, especially at the time when the pumps are required to raise the maximum quantity of sewage, it is necessary to have a much more expensive type of pump, such as a Triple Expansion Steam Pump.

In these high-class pumps must work uneconomically for a great part of the time when the conditions are not those for which they were designed. They have to be designed to raise the greatest quantity against the maximum head. Therefore at other times—that is most of the time—the pressure against which they are working is less than that for which they were designed, and the full benefit cannot be obtained from the high pressure steam.

(3) Gravitation mains are very much cheaper than cast-iron mains. The saving increases with the size of main. Generally speaking, with the size required for Madras, the cost of gravitation mains is about one-quarter of the cost of cast-iron mains.

Benefit of gravitation mains in the system now proposed.

92. In the scheme now put forward the areas drainable to the pumping stations have in several cases been largely increased by the use of gravitation mains. This is especially the case in the area draining to the Purasawakkum Pumping Station where the gravitation main has rendered it possible to dispense with a large number of deep pipe sewers which would otherwise have to be laid. It also renders possible the draining to one single pumping station the whole Purasawakkum area, which otherwise would require three stations. Other areas which are considerably benefitted are the Ice House Road by Gravitation Main No. 3, and the Lang's Garden area by Gravitation Main No. 4. If an entirely new scheme had been possible, the system of gravitation mains would have been very much more largely used, but with a view to utilising the existing sewers and especially the cast-iron main as much as possible, it has not been practicable to carry out the principle of gravitation mains to its fullest extent.

Utilisation of existing sewers.

93. As already stated, the existing sewers will be utilised as far as possible. The smaller collecting sewers are large enough for the streets which they serve, and with proper means of excluding silt and storm water, and adequate flushing arrangements, some of them will give good service. The larger of the existing

mains are in some cases too small for the quantity of sewage which it is estimated they will ultimately have to carry, but the calculations for these quantities are made in accordance with first-class practice, and the new sewers are made capable of carrying at least 5⅓ times the estimated dry weather flow of 1961. It may be many years before this limit is reached, and it may be that water coming to the sewers will not be as much as is expected. For these reasons then the sewers which are slightly small, may for many years be quite serviceable. They will not be replaced until it becomes necessary to do so.

A good example of this is afforded by the "A, B, C Main" which conveys most of the sewage of Triplicane to Napier Park Pumping Station.

Numerous observations have shown that this main is usually gorged during the day time with the ordinary dry weather flow. In order to ascertain the true conditions of working of this sewer, a number of experiments were carried out to determine the hydraulic gradients. The results of two series of experiments, carried out on different days, are plotted on the diagram forming Plate VII facing this page.

The experiment of 9th September may fairly be taken to represent normal conditions of working.

The experiment of 21st August was carried out with the engines at Napier Park Pumping Station working under the immediate supervision of the Mechanical Engineer, with a view to obtaining the best results possible. In both cases only one of the two engines was working.

There was some depth of silt in the sewer: when this is taken into account the results confirm the theoretical calculations within the limits of accuracy of the experiment.

Thus for the 21-inch sewer between A and B, taking the maximum hydraulic gradient on August 21st which occurs at 11 A. M., and calculating the flow, with a due allowance for silt, the maximum discharge works out to be about 740 gallons per minute with a velocity of 1¼ feet per second.

If will be seen that between A and B the hydraulic gradient line is flatter than the gradient of the pipes, showing that the sewer is large enough to take the sewage now brought to it, even though the pipes are partly filled with silt. Higher up the effect of the silt is greater on the discharging capacity of the smaller sewer.

In a sewer working properly the hydraulic gradient lines should lie wholly inside the sewer: the diagram (Plate VII) shows how far this condition is from existing in the A, B, C Main.

From measurements of the size and gradient of the sewer, it is calculated that it is large enough to take all the sewage that will drain to it under present conditions provided that—

(1) The sewer be kept clean.

(2) The pumps be worked regularly to prevent the sewage backing up and the deposit of silt.

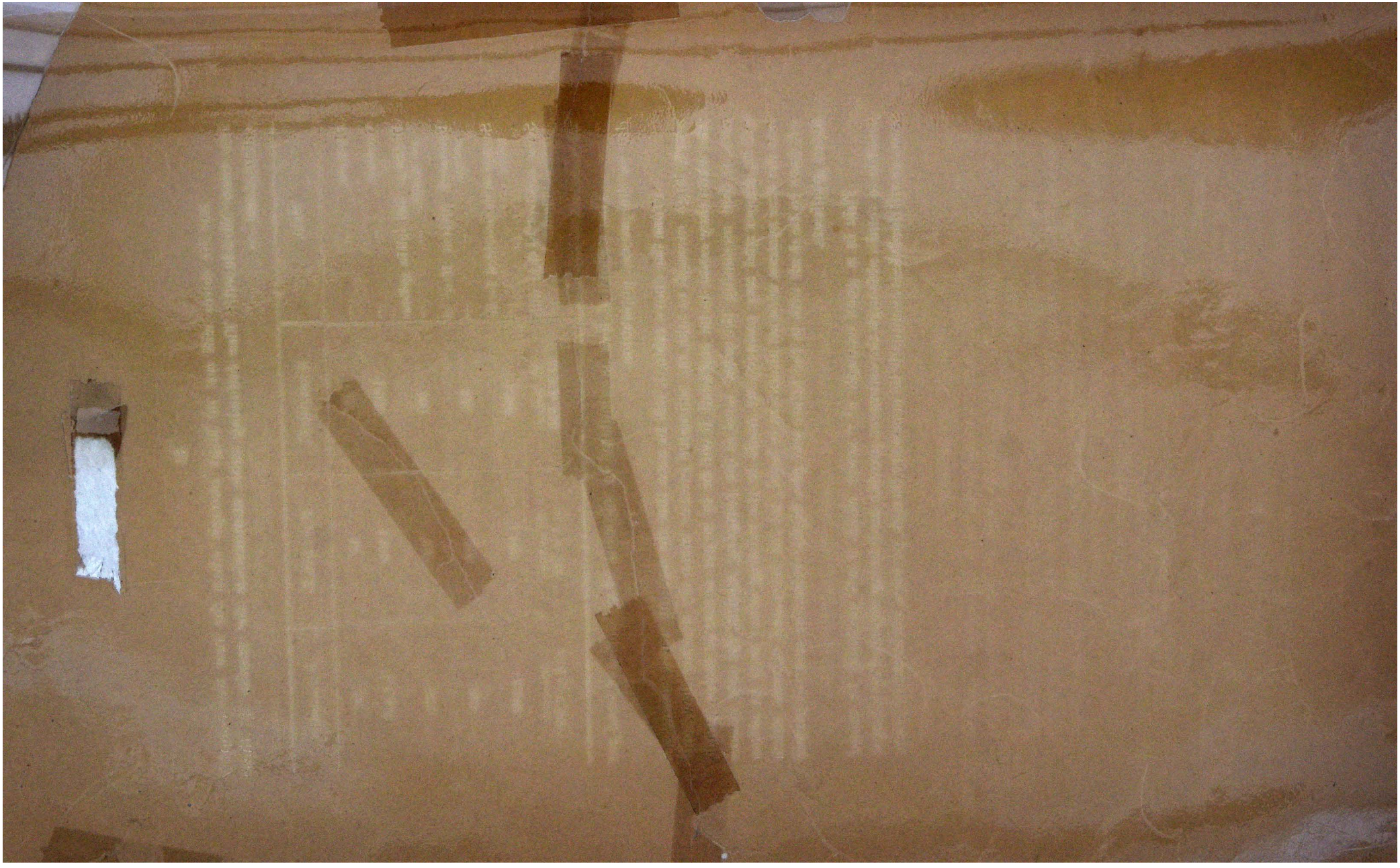
But the sewer will not be large enough when the new water-supply has been introduced. The following table summarises the results of these calculations :—

Main.	B towards C.	B towards E.	B towards A.
Diameter	15″	12″	21″
Gradient	1/833	1/666	1/1,100
Discharge half full in gallons per minute	456	280	972
Estimated present flow of sewage	346	217	563
Sewage to be provided for in future	1,700	1,065	2,800
Sewer required to deal with sewage in future ...	26 inches at 1 in 950	21 inches at 1 in 720	33 inches at 1 in 1,300

The estimated flow is calculated by allowing 16 gallons per head per day for the present population.

From the above table, it will be seen that the existing trunk sewers are amply large enough to take the estimated present mean dry weather flow, and that when they come to be replaced, it will be by larger sewers at flatter gradients, so that assuming the same level at the pumping station, the new sewers will be deeper and any connections made to the existing sewer may be taken into the new system without alteration in level; for the increased volume which will have to be dealt with in the future will give higher velocities and yet permit flatter gradients.

This is a good example of a sewer which it will probably be found possible to retain although the estimates provide for it being replaced by a larger sewer as will doubtless eventually be necessary though, perhaps, not for many years.



CHAPTER VII.

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Works Proposed.

Introduction and summary of works proposed.

94. The purpose of this chapter is to assist the reader to obtain a general idea of the work proposed. No attempt will be made to give anything more than an outline description of the works.

A detailed description would occupy a great deal of space and would not be so clear as the drawings themselves.

The following is a brief summary of the principal works comprised in the scheme proposed in this report :—

Pumping Stations.

	No. of Stations.	No. of Pumping Sets.	Approximate Brake Horse Power.
Number of new stations	8	26	660
Do. stations in course of construction...	4	14	650
Do. existing stations to be retained ...	2	5	220
Totals ...	14	45	1,530

Sewers.

The lengths of sewers in the completed scheme will be as follows:—

Diameter of Sewers.	Old Sewers to be removed.	Old Sewers to be retained.	New Sewers to be laid.	Sewers now being laid in Tondiarpet.	Total length in the completed scheme.
			Stoneware Pipe Sewers.		
	Feet.	Feet.	Feet.	Feet.	Feet.
6″	49,269	51,450	462,000	102,000	664,719
9″	63,270	6,840	398,000	35,000	503,110
12″	15,600	5,200	59,000	9,000	88,800
15″	2,900	...	34,000	5,800	42,700
18″	10,900	11,220	19,000	2,000	43,120
21″	4,180	...	21,000		25,180
Totals ...	146,119	74,710	993,000	153,800	1,367,629
			Cast-iron Pipe Sewers.		
24″	3,480	...	6,300	4,300	14,080
27″	1,520	...	2,800	...	4,320
30″	1,200	...	4,200	...	5,400
	3,950	...	3,900	...	7,850
..	10,150	...	17,200	4,300	31,650

New Brick Sewers.

2 feet 3 inches diameter	...	...	...	...	...	7,392	feet.
2 „ 6 „	„	...	..	...	...	1,385	„
2 „ 9 „	„	...	...	...	...	3,138	„
3 „ 0 „	„	...	...	...	...	2,615	„
4 „ 0 „	„	...	...	...	...	1,140	„
4 „ 6 „	„	...	...	...	..	3,794	„
4 „ 9 „	„	...	...	...	...	868	„
5 „ 3 „	„	...	...	...	...	1,055	„
5 „ 6 „	„	...	...	...	...	5,750	„
				Total	...	27,137	feet.

House Connections.

Approximate No 40,000
4-inch pipes for house connections ... ...500,000 feet.

Summarised.—The sewers will consist of —

New stoneware pipes 6 inches to 21 inches	...	259	miles.
Old pipes to be retained	... ...	14	„
New Cast-iron Pipes...	... ...	6	„
New Brick Sewers	... ...	5	„
	Total ...	284	miles.
Add house connections 500,000 feet or		95	„
Total length of sewers and house connections	...	379	miles.

Sewer System.

General description.

95. The detailed lay-out of the system proposed must be studied from the sewer plans on which are shown the sewers proposed for each area and the contours marking the level of the ground. The sizes of the sewers are indicated by different colours. Besides the sewer plans, there are a number of sheets of sewer sections which show the ground levels, sizes and gradients of the sewers and the positions of the manholes. To avoid complication the gravitation mains and intercepting sewers are not shown on the pipe sewer plans. They are shown separately on special large scale plans and sections.

It will be seen that for the part new sewers are proposed throughout the city. Provision has been taking up many of the existing sewers and replacing them with new pip at steeper gradients and conforming in other respects also with good p . This wor will, however, be postponed wherever it appears possible that the existing sewers may be made to give satisfactory service. In these cases, the existing sewers will be replaced only when they are found to be quite unsuitable. On the other hand, some of the existing sewers which are shown on the plans as being retained may have to be taken up. For instance the sewer in Waller's Road, Chintadripet, is now being relaid because the old sewer has collapsed. On digging down, it was found that the old pipes were made of concrete. There is no record in the Corporation Office that concrete pipes were laid here, and it was intended to retain this Waller's Road sewer. Doubtless there will be other sewers in an equally unsatisfactory condition, but it is believed that the estimates will prove sufficient to cover the cost of replacing them. The heads of 6-inch pipe sewers are generally placed about 3 feet below ground level, but in some cases are started at a greater depth, especially in residential districts where the compounds are large and the bungalows at considerable distances from the road. The sewers are kept deep to enable them to drain these bungalows In the case of some bungalows situated a long way back from the roads, it may be necessary to start the house drain at or even above ground level. For this reason, amongst others, it is highly desirable that there should be a stipulation in the building byelaws that all floors and courtyards inside a building should be at least one foot above the crown of the road.

Area draining to Mylapore Pumping Station (Drawings Nos. 99 to 103).

96. Drawing No. 99 shews the areas draining to the two Mylapore Pumping Stations. That on the East is adjacent to the existing pumping station and that on the West is the area draining to a proposed new pumping station which is required to deal with the sewage of Robertsonpet and the south-western part of Mylapore. The plans and estimates for this area provide for completely relaying the sewers, many of which are cement pipes and are likely to fail in the course of time The work in this area is not so urgent as in many other parts of the city Those parts that are at present undrained are outlying districts where the density of population is not great and where most of the sewage can be turned on to land. The conditions resulting from want of drainage are therefore not so insanitary as they are in more crowded districts.

Drawings Nos. 100 to 105 show sections of the proposed new sewers which vary in size from 6 inches to 18 inches.

Area draining to Edward Elliott's Road Pumping Station (Drawings Nos. 106 to 110).

97. Drawing No. 106 shows the sewers proposed for the area draining to the new Edward Elliott's Road Pumping Station All the sewers proposed are new, for at present this area is unprovided with any underground drains To the East of the area are shown the Gravitation Main No. 3 leading to Ice House Road Pumping Station, and the sewers which drain to it. The sewers proposed for the Edward Elliott's Road area are designed rather larger than necessary for the increase in population which is expected during the next fifty years. They are, however, not too large if the area becomes fully built up, as may easily be the case should a general town planning scheme come into existence under which the surplus population of Triplicane would be moved southwards to this area. The depths of the sewers are not great and it may quite well be hat the gradients will be made a little steeper. Before this can be decided, however, more trial holes must be got out. When the work in this area is within measurable time of being started then the scheme will be carefully considered with a view to improving gradients, if possible.

At the present time, underground drainage is not so urgently required in the Edward Elliott's Road area as in other parts of the city, and the laying of sewers may be postponed for some years while work on sewer laying is concentrated on Purasawakkum, Triplicane, Georgetown, and other more densely-populated areas. There is no need to delay the work of other areas in order to work out the minute details of the drainage of this area. Unexpected new roads may be constructed and unexpected movements of population may take place. and these conditions would require the modification of any scheme that could be drawn up at the present time. The only work that should be put in hand at a very early date is the laying of the gravitation main to the Ice House Road Pumping Station. This gravitation main is required to drain the inhabited area to the west of Meeran Sahib Street, which belongs properly to the Ice House Road area, though it has only been rendered possible to drain it to Ice House Road owing to the considerable volume of sewage that will flow from the Edward Elliott's Road Pumping Station. This gravitation main is shown to commence some 700 feet to the east of Venkatachala Mudaly Street, but there is no reason, except the difficulty of draining the area north of Edward Elliott's Road, why the Pumping Main No. 3 from Edward Elliott's Road Pumping Station should not be continued eastward for another 1,000 feet or so, in which case the gradient of the gravitation main will be improved. This is a point that will be determined as soon as the execution of the work is definitely decided upon.

Drawing Nos. 107 to 110 show sections of the sewers proposed for the Edward Elliott's Road area.

Ice House Road Pumping Station area (Drawings Nos. 111 to 118).

98. Drawing No. 111 is a sewer plan of the area draining to Ice House Road Pumping Station. Starting from the Pumping Station, the deepest sewer is a cast-iron pipe 30 inches in diameter which enters the pump well at a level 4 feet below sea level. The other sewers are of stoneware pipes. The sewers of this area are

shown to be wholly relaid, and the new main sewers are at lower levels and at steeper gradients than the existing sewers. The most western portion of the existing area will be taken into the new area known as the Nungambakkum Pumping Station area. Sewer laying in the Ice House Road area is not of very great urgency. The present sewers should do their work much better when adequate pumping plant has been installed. The most urgently required appears to be the Ice House Road sewer, but before relaying it, the effect of improved pumping at Ice House Road Station will be ascertained.

Drawings Nos. 112 to 118 show sections of the sewers. It will be seen that at the head of the main sewer it has been possible to provide a gradient steeper than the ordinary minimum.

Napier Park Pumping Station area (Drawings Nos. 119 to 128).

99. Drawing No. 119 is a plan of the sewers of the area draining to Napier Park Pumping Station. It will be seen that a number of the existing sewers (shown by fine lines) are to be retained, especially in Chintadripet. It is possible, however, that some of them will have to be relaid. For instance, the Waller's Road sewer is shown to be retained. Since the plan was prepared the concrete pipes of which this sewer was composed have collapsed [illegible] been necessary to relay it with stoneware pipes throughout. The majority of sewers in Triplicane are shown to be relaid, but before doing this it is proposed first to see what will be the effect of improved pumping plant at the Napier Park Station. With efficient pumping plant, with proper methods of excluding silt, and with all the numerous improvements which will be effected, the existing sewers will be rendered very much more efficient, and it is likely that a number of them will give satisfactory service for many years to come. Before preparing the contract plans, every individual sewer will be examined in a manner which is not possible at present on account of the backing up due to ineffectual pumping.

Drawings Nos. 120 to 128 show sections of the sewers. These do not call for any special remarks It will be observed that in most cases, satisfactory gradients are obtained—considerably steeper than the ordinary minimum gradients that are allowed.

Drawing No. 128 shows a plan and section of the Waller's Road Sewer which, as stated above, has been relaid. This is a good example of the way in which the gradients may in most cases be improved during relaying. A considerable amount of water was encountered in the lower reaches of the sewer which at its discharge end has its invert 2 feet below sea level. The experience with this sewer confirms the opinion already arrived at—that the sewers in this area can be laid down to some 6 feet below the sea level, though it is needless to say that the work at such depths will be expensive and the progress slow. At the same time, the expense is fully justified by the saving effected by keeping the number of pumping stations as low as possible.

Graeme's Road Pumping Station area (Drawings Nos. 129 to 134).

100. Drawing No. 129 is a sewer plan of the area draining to the Graeme's Road Pumping Station. The drainage of most of this area is not very urgent. The sections which are most in need of sewers are Teynampet on Mount Road, the large business premises on Mount Road, Thousand Lights and Mackay's Gardens

Drawings Nos. 130 to 134 show sections of the sewers. Some of them are slightly too large for present requirements. They are not too big, however,

should the district grow rather more quickly than is at present anticipated. It is difficult to say how the present sewer lay-out can be improved without going to greater depths. As will be seen from the sections, some of the excavations will be as deep as 21 feet below ground level and others will extend to 5 feet below sea level. This is as deep as it is safe to lay the pipes in this area

Lang's Garden Pumping Station area (Drawings Nos. 135 to 138).

101 Drawing No. 135 shows a plan of the sewers draining to the Lang's Garden Pumping Station, as they will be in the completed scheme. It will be noticed that a considerable portion of this area is already sewered and that many of these sewers will be retained. The main sewers will, however, have to be deepened, in order to extend the limits of the area which can be drained to the pumping station.

An important [illegible] ture of the scheme for this area is the proposed Gravitation Main (No [illegible] hich brings in the sewage pumped from the Graeme's Road Station throu[illegible]rn exis[illegible]ing Main No. 4. By the use of this gravitation main conveying a c[illegible]. It is no[illegible]olume of liquid, it is possible to provide a sewer which carries [illegible]st section of [illegible]e area right up to the Cooum opposite the Connemara Hotel. O[illegible]e laid d[illegible] of its great depth and the large quantity of water that will [illegible] encou[illegible]tered the lower section of this gravitation main will be laid with 24-inch cast-iron pipes for a distance of 1,600 feet.

Drawing Nos. 136 to 138 show sections of the Lang's Gardens area [illegible]rs. In most cases, the mains are slightly larger than would be required for [illegible]timated population; but here again it is considered advisable not to have them too small. All the existing sewers will be carefully examined before preparing the contract drawings, as it may be that some of those shown to be retained will prove to be unsatisfactory.

Purasawakkum Pumping Station area (Drawings Nos. 139 to 156).

102. Drawing No. 139 is a plan showing the area draining to the proposed new Purasawakkum Pumping Station. More time has been given to the planning of the sewer net-work of this area than to any of the others At first it appeared necessary to have three pumping stations for this area and plans were prepared on that basis. Subsequently as a result of trial holes, it was concluded that it was possible to lay sewers at a greater depth than in most of the other areas of Madras, and the main sewers at the pumping station are shown to extend as low as 8 feet below sea level. These sewers will of course have to be laid very carefully, and will take some time to complete, as the trenches will have to be very securely timbered. The advantage of draining such a large area to one pumping station is very great, and more than compensates for the extra cost of sewer laying which will indeed be more than counterbalanced by the saving effected by eliminating the additional pumping stations.

A prominent feature in the drainage of the Purasawakkum area is Gravitation Main No. 5, which begins at the extreme south of the area. It is not shown on the sewer plans or sections, but it is plotted to a larger scale on Drawings Nos. 46 to 55. At its head this gravitation main receives the discharge of Pumping Main No. 5 bringing the sewage pumped from Lang's Garden Pumping Station. The considerable volume of sewage which flows down the main makes it possible to lay it as a large intercepting sewer at a flat gradient, and consequently to extend the area greatly beyond the limits to which it would be confined if there were no gravitation main.

It has been found necessary to allow for relaying very nearly all the sewers of the Purasawakkum area. The existing sewers are very difficult to maintain in satisfactory working order, and decidedly steeper gradients are required. It has been possible to lay out practically all the sewers in this area to the ordinary minimum gradients and they are all nearly of the size suitable for the population for which the scheme is designed. A few of the main sewers have been laid at the flattest gradients allowed, mostly in the lower reaches where the volume of flow is more constant than in the smaller collecting sewers. It has been possible to lay out a large number of the branch sewers at good gradients. Thus as much as 17,700 feet of 6-inch pipes are shown at the steep gradient of 1 in 60.

Drawings Nos. 140 to 156 show sectio[illegible] f the sewers proposed with the exception of the Gravitation Main No. 5 whic[illegible] already stated, is shown in detail in Drawings Nos. 46 to 55.

Georgetown Drainage (Drawings Nos. 157 to 181).

103. Drawing No. 157 is a plan of the sewe[illegible] drain the George-town area which extends from the Railway on the [illegible]ne General Hospital on the south, and from the sea on the east to the Bucking[illegible]n Canal on the west.

Georgetown is divided into two areas. [illegible] southern wi[illegible]a to the new pumping station opposite the Law Colleg[illegible], and the northern area will drain to the Rayapuram Pumping Station at the north-east of Georgetown nearly opposite Rayapuram Railway Station. The boundary line between the two areas is shown on Drawing No. 157 by a heavy broken black line running approximately from east to west close to Errabaloo Chetty Street and Andi-appa Naick Street.

The Georgetown area is at present drained by means of open drains which discharge into intercepting sewers. These intercepting sewers will be utilised as far as possible, but a considerable portion will have to be replaced.

The new pumping station at Law College and the Rayapuram Pumping Station with its new engines and pumps are the most efficient stations in Madras. The sewer laying of this area can be put in hand without interfering with the most urgently required work in other areas, and it is therefore proposed that street sewers in Georgetown should be taken up as soon as the pipes are obtained in order that the present mal-odorous and insanitary side drains may be dispensed with and that the full benefit of the new pumps may be obtained.

Georgetown is the most densely-populated area of Madras. Its inhabitants include many wealthy merchants and other persons of high standing in Madras. This area should therefore receive particular attention in sanitary matters. At present the gases produced by the decomposition of sullage in the side drains are everywhere inhaled.

Underground drainage will render this important part of the city incomparably sweeter, cleaner and more pleasant to live in.

Law College area.

104. To drain the Law College area, th[illegible]most western of the [illegible]ting intercepting sewers (that along the Wall Tax Road) will be retained as far as China Bazaar Road. At this point the sewage will be intercepted by the 21-inch pipe which will convey it to the Law College Pumping Station. This 21-inch pipe

will also take all the sewage of the Law College area to the north of it. The Fort drainage, though not shown on this plan, can also be dealt with at Law College Pumping Station, and the writer understands that a scheme is in preparation for draining the Fort and delivering its drainage at such a level that it will run readily to Law College Pumping Station through a 9-inch pipe sewer.

Area draining to Rayapuram.

105. The existing sewer along the Beach Road will be used almost as far as Kandappan Street, where the sewage will be taken on by a 24-inch cast-iron main delivering into the new 36-inch cast-iron main coming down from Old Jail Street. The existing central intercepting sewer running along Popham's Broadway will be replaced by a new sewer which, for about 2,700 feet, will consist of 24-inch and 27-inch cast-iron pipes delivering into the 36-inch cast-iron pipe in the Old Jail Street.

The most westerly existing sewer, leaving Wall Tax Road, runs largely through private lands and is not conveniently situated to intercept the drainage of the westernmost portion of Georgetown and will be abandoned. A new intercepting sewer will be laid down Wall Tax Road as far as Peddu Naicken Street whence it will turn into the Old Jail Street and continue in cast-iron pipes as far as Rayapuram Pumping Station. About 8,000 feet of this sewer from the Pumping Station will consist of cast-iron pipes varying from 24 inches to 36 inches in diameter.

Drawing Nos. 158 to 164 show sections of the sewers in the Law College area and Nos. 165 to 181 sections of the sewers in the Rayapuram area.

Area draining to North Tondiarpet, D and E Stations

106. Drawing No. 182 shows the arrangement of sewers proposed for North Tondiarpet. This area is, however, not yet ripe for sewering. Detailed estimates of the work shown on the drawings are given in an Appendix to the estimates. They have not been included in the totals for the general scheme, but an allowance of 2 lakhs of rupees has been made for such work as may be necessary, for instance, the drainage of Pudu Wannarapet which may be pumped straight into the Open Channel.

Pumping Stations.

Existing Pumping Stations unsuitable.

107. The existing pumping stations are of two classes: either they are of masonry type which is unsuitable, or they are of corrugated sheet structures which are falling into decay. The question of utilising the existing pumping stations has been carefully considered. The conclusion arrived at is that in every case, it is better to erect a new pumping station than to try to modify the existing station. Such modification would be unsatisfactory, and the difficulties that would be encountered in altering the station and furnishing it with new machinery, without interfering with the pumping, would be very great.

Type of pumping stations proposed (Drawings Nos. 8 to 20).

108. Drawings Nos. 8 to 20 show the designs for the proposed pumping stations in as much detail as is possible before the machinery to be installed has been decided upon. The class of machinery proposed is set out in the table given in paragraph 127. The type of pump to be finally adopted at any partic-

ular station is subject to modification. In the years that will intervene between the submission of these designs and the completion of some of the pumping stations, new developments in pumping machinery may take place which will render more satisfactory a type of plant totally different from that proposed. As an illustration, the recently-developed Humphrey Pump may be instanced. The writer himself has done some work on a type of pump which he thinks will be satisfactory for lifting sewage, but since coming to Madras he has been too busy to continue his researches. None of the existing types of sewage pumping plant are really efficient and satisfactory. There is plenty of room for a new and more satisfactory design.

Mylapore Pumping Station.

109. Drawing Nos. 8 to 10 show the pumping station proposed for Mylapore. This is typical of the design for the stations to house steam or oil pumping plant, and it is on this type of design that all the stations, namely, those at Mylapore, Edward Elliott's Road, Ice House Road, Napier Park, Graeme's Road, Lang's Garden and Purasawakkum have been designed, the sizes varying to suit the different types and powers of the plants proposed to be instal ed The details proposed for the Mylapore Pumping Station (for instance the gothic windows) are rather more elaborate than in most of the other pumping stations for the reason that the Mylapore station will be close to the Marina which is such a fine feature of Madras that it is very undesirable to have it disfigured by an unsightly building.

Edward Elliott's Road Pumping Station (Drawing No. 11).

110. The site of the proposed new Edward Elliott's Road Pumping Station is shown on Drawing No. 11. The least area required is that within the compound wall shown in red. It is, however, desirable to take up the whole plot of which this forms a part. The tank may be largely filled up with surplus excavation from the pipe laying, screening chambers, pump wells, etc. The additional ground beyond the minimum required for the pumping station will be of value for stores-both for water-works and drainage works. An application has already been made for the acquisition of the whole area with a view to storing articles required for the new water-works.

Ice House Road Pumping Station (Drawing No. 12).

111. The site of the proposed new pumping station at Ice House Road is shown on Drawing No. 12. This is adjacent to the existing pumping station which is unsuitable in arrangement, for it involves two boilers so placed as to lose a good deal of heat and to require two chimneys. The pumping well requires deepening considerably and this would be an impossible operation to perform without diverting the sewers coming to the old station and constructing a temporary pump well with all the necessary temporary suction pipes, etc. In addition, silt pits and screening chambers with their necessary appliances have to be constructed. For these reasons it is best to construct an entirely new station.

Napier Park Pumping Station (Drawing No. 13).

112. Drawing No. 13 shows a part plan and sections of the station proposed for the Napier Park area. The main feature of this station in which it differs from the other stations is that there are two suction troughs, the high level at about sea level, and the low level at about 9 feet below sea level. The high level trough is for the sewage pumped by the Mylapore, Edward Elliott's

Road and Ice House Road Stations, which it is desirable to pump again, in order to divide the total lift into two stages. The low level suction trough is for the sewage draining from the area directly commanded by the Napier Park Pumping Station. Should the sewage in the high level trough ever be too great for the pumps, it can overflow down a 18-inch cast-iron pipe into the low level suction trough.

As will be seen from the drawing, the four sets of pumps are arranged with double suction pipes commanded by valves, so that they may draw off from either trough as may be desired.

The object of having two troughs is to avoid the expense of raising half the sewage some 9 or 10 feet more than necessary. The sewage coming from the south is at a comparatively high level and considerable extra expense would be incurred if it were dropped some 9 or 10 feet to the level of the main sewers of the Napier Park area.

A branch pipe, not shown on Drawing No. 13, will also be provided, in order that the high level trough may be emptied for cleaning or other purposes and the whole of the sewage pumped from low level trough.

Graeme's Road Pumping Station (Drawing No. 14).

113. Drawing No. 14 shows a site plan of the Graeme's Road Pumping Station with a small scale elevation and sections. Provision is made for three sets of Oil Engines and Centrifugal Pumps. This station is shown to be furnished with the usual collecting wells, silt pits, screening chambers, offices, etc.

Lang's Garden Pumping Station (Drawing No. 15).

114. The existing steam engine pumping station at Lang's Garden will be dispensed with, and a new Oil Engine Station constructed as shown on Drawing No. 15 which gives a site plan of the proposed new station, together with small scale elevation, and section through the collecting well, silt pits, screening chamber and pumps. The existing station can, with some modification, be used for a Nightsoil Depôt, such as the Health Officer is anxious to have installed in this neighbourhood. In that case, the existing chimney would be used for taking off the offensive gases. This should largely reduce the smell which is inseparable from Nightsoil Depôts.

Purasawakkum Pumping Station (Drawing No. 16).

115. The new station which it is proposed to construct to the north of the Purasawakkum area is shown on Drawing No. 16. This station is designed to accommodate four sets of Oil Engines and Centrifugal Pumps. The drawing shows a plan of the station together with elevation and sections. It will be seen that the type of structure is very much like the other pumping stations, the main difference being that it is larger in order to provide for the larger plant proposed.

Typical details of Pumping Stations (Drawings Nos. 17 to 20).

116. *Roof* —Drawing No. 17 gives details of a typical Engine and Boiler House Roof. The roof shown consists of cement concrete 4 inches thick, reinforced with expanded metal supported on rolled steel beams running the whole width of the roof. The steel beams will rest for one foot at their ends upon smooth dressed granite stone templates 15 inches by 12 inches by 6 inches. A thin layer of 1 to 1 cement mortar will be placed between the templates and the girders to form an even bearing surface.

The main girders shown on Drawing No. 17 are 18 inches by 7 inches rolled steel beams weighing 75 lbs. per foot run. These will be modified according to span of the roof. They will be connected by arch ribs formed of 4 inches by 3 inches steel beams weighing 9½ lbs. per foot run, surmounted by fine concrete to form a flat topped curved re-inforced concrete rib. The end of the ribs will be attached to the girders by small bond plates as shown in the enlarged details X–Y. On the grid of steel beams and re-inforced ribs will be placed 4 inches of fine cement concrete re-inforced with mild steel expanded metal ¼ inch by ⅜ inch by 3 inches meshes embedded for half an inch in the bottom layer of concrete. The concrete used will be made of clean granite stones broken to pass through ¾ inch mesh screen mixed with cement and sand in proportions of 1 cement, 2 sand and 3 stone. To ensure that the roof shall be water-tight, it will be covered with a layer of malthoid. This type of roof, with modifications to suit the span, is proposed for all pumping stations, but will be modified if found desirable or economical as the work proceeds. It has proved quite satisfactory in the new pumping stations where it has already been used.

Offices, stores, etc. (Drawing No. 18).

117. It is proposed to provide every pumping station with workshop, store, office and latrine. Drawing No. 18 shows the type of offices proposed. The drawing shows the work proposed in such a detail that no description is here required. The latrine will be of the Madras Standard patterns as designed in the Special Works Department (*see* Plates XIV and XV).

Doors, windows, compound walls (Drawings Nos. 19 and 20).

118. Typical doors and windows as designed for estimate purposes are shown on Drawing No. 19. Drawing No. 20 shows a typical compound wall. These two drawings also show the work proposed in such a detail that no description need be given.

Silt pits, screening chambers, etc.

119. Each pumping station will be provided with a collecting well into which the sewers will deliver. From the collecting well, the sewage will flow through silt pits and screening chambers which are to be provided in duplicate. One or other of two types of such chambers will be adopted, according to the nature of the ground encountered. If the ground contains a large quantity of water and is such that the bottom is liable to "blow" when deep excavations are made, then separate circular wells will be sunk as follows:—

No. 1, about 6 feet in diameter for the collecting well.

No. 2, 12 to 20 feet in diameter for silt pits and screening chambers.

No. 3 or 4, 6 feet in diameter for the pump wells.

If the ground is good, so that excavation can be readily taken out, then timbering may be employed and one large chamber divided into partitions, and providing silt pits and screening chambers in duplicate, may be used instead of the separate well system.

In any case circular wells are proposed for the pump suctions. Not only will they serve as suction pits, but they will also provide excellent foundations for the pumps themselves.

Arrangement of silt pits and screening chambers (Drawing No. 21, Plate VIII).

120. With the circular well system, the incoming sewage first enters the circular receiving chamber whence it can be turned so as to pass through one or both of a pair of combined silt and screening chambers. These are circular brick wells with the bottoms formed as inverted cones. The inlet and outlet pipes are connected with these chambers at the top of the cone. The sewage entering by the inlet pipes loses its velocity in the large area presented by the pit, and the silt and other heavy materials in suspension drop to the bottom and are from time to time removed by a "silt raiser" of a design which has been patented by the writer, and illustrated on Drawing No. 21. It consists of a fixed Tee pipe suspended over the centre of the silt pit. Inside this slides a movable pipe, the bottom end of which can be dropped on to the top of the silt, while the top end remains within the Tee pipe at a point below the branch. The branch leaves the pit some two or three feet below the top and leads to a settling basin at or about ground level. The operation of raising the silt deposited in the cone shaped depression of the silt pit is as follows:—The valves on the inlet and outlet pipes are closed. The chamber is filled from the pump discharge and the valve on the Tee pipe branch is opened. There is then a head of some 2 feet 6 inches tending to drive the liquid in the silt pit up the movable pipe and out through the Tee piece branch to the settling tank. The bottom of the movable pipe is kept close to the surface of the silt and the liquid in rushing up the pipe scours away the silt and carries it up and out along the branch to a small settling basin, where the clear liquid is siphoned off and the deposited silt is subsequently shovelled into carts. These arrangements are clearly shown on Plate VIII.

Drawing No. 21 shows a typical silt pit and screening chamber with a silt raiser at its lowest position. This arrangement is similar to that which has been adopted at the new Law College Station. Here the silt-raiser is operated every morning as a matter of routine, and the silt is removed before any great quantity accumulates. The cleanliness of this method of removing the silt is very marked as compared with the filthy method employed at the old stations where divers are employed. These men have frequently to submerge themselves in sewage and scrape away the mixture of silt and leaves which rapidly collects close to the pump suctions.

Screens (Drawing No. 21).

121. Screens are fixed on the outlet side of the silt pits. They consist of light cages made of steel rods, well painted to preserve them from corrosion. When a cage is sufficiently charged with refuse it is raised above the top of the chamber by means of a light hand crane and swung over a cart. The flap door forming the bottom to the cage is then opened by releasing a catch and its contents dropped into the cart. The interior of the cage is then scraped down lightly with a rake, the door slammed up and the emptied cage let down again to its original position in the sewage flow.

Drawing No. 21 shows a typical screen as proposed. Similar screens are now working at Law College and Rayapuram Pumping Stations and have proved successful. The type shown on Drawing No. 21 has been improved in some respect where experience has shown that it is desirable.

Pump suction wells.

122. From the screening chambers the sewage flows to three or more pump suction wells—one for every pump—each 6 feet in diameter. Each small well is connected separately to the outlet pipe from the silt and screening pits. For

porous ground containing large quantities of water such as that encountered in the north and east of Madras, this multiple well system is much cheaper and easier to construct than a single large well, for the small pits can be sunk without any timbering, and with an ordinary amount of care water tightness can be readily ensured under a head of 15 to 20 feet of water.

Well method of executing underground work (Drawings Nos. 22 and 23).

123. The method of well sinking will be the same as that which has proved so successful in Tondiarpet, and at the Law College and Rayapuram Pumping Stations. Wherever possible, all deep underground masonry work in Tondiarpet, such as screening chambers, silt pits and pump wells has been constructed by means of wells sunk vertically downwards. It was the only practicable method in this area on account of the large amount of water brought freely to the excavation through the coarse sand beds that are encountered. At several pumping stations this quantity of water was estimated to be from 20,000 to 30,000 gallons per hour when nearing the bottom of the wells. In consequence of this flow and the considerable pressure—often over 20 feet of water—continual bursts of sand at the bottom took place whenever an attempt was made to keep down the water. To overcome this difficulty, the water was kept 10 to 12 feet deep by means of pumps and the excavation was got out by means of divers. By this method, blowings were obviated and the quantity of water that required pumping was considerably decreased. After the wells had been sunk to the required depth, the water was allowed to rise to its natural level and the bottom was sealed with cement concrete. The usual method of depositing the concrete was to place the bottom layer in gunny bags. Over this, concrete was deposited either by pouring through a long tube, or alternatively by means of buckets which were tipped when they reached the bottom. Both methods were equally effective when carefully done. During the operation of depositing concrete the water was allowed to stand at its natural level. There was therefore no flow through the cement concrete which had every opportunity to set during the week for which it was left undisturbed. In no case was there any leakage beyond very small weeps of water which were easily stopped, although a head of water on the bottom of the well exceeding 20 feet was not unusual.

Drawings Nos. 22 and 23 show the type of well and especially the curb and steel re-inforcement which is used in sinking the wells. The ground is first excavated down to the level of the subsoil water and the light steel re-inforcement for the curb made of light bars 4 inches by $\frac{3}{8}$-inch is put in place. A rough mould is then made of dry bricks set in mud, and the concrete forming the curb is put in place. The brick-in-mud mould is removed as soon as the concrete has thoroughly set, and the brickwork above is commenced. The brick work is tied together by means of vertical 1-inch iron pipes—six in number in the case of 6 feet diameter well, and eight in number in the case of 10 feet diameter well. To these iron pipes are attached light bond steel plates 3 inches by $\frac{3}{8}$ inch every 6 feet vertically. They are secured firmly by means of nuts and screwed couplings.

Combined chamber system.

124. The combined chamber system is exactly similar to the separate well system just described, except that, instead of two separate circular wells for the screening chambers and silt pits, one combined chamber is used with partitions so arranged as to provide silt pits and screening chambers in duplicate. This is

the system which is shown on the drawings—for example Drawing No. 11. It has the advantage of being more compact which is an important point in those cases where space is limited. This is the system which has been provided for in the estimates because it is more expensive than the single well system, and therefore if it is found that the single well system must be adopted for constructional reasons, there will be no additional cost over that provided for in the estimates.

Proposed Pumping Plant.

Proposed new Sewage Pumping Stations.

125. The results of working and of the experiments described in Chapter XVII show that the pumping plant now in use is totally inadequate to deal with the sewage that will flow to the different stations when the new water-supply has been introduced, and when a large proportion of sullage, which is now allowed to soak into the ground, is all taken into underground sewers. The following table shows to what extent the existing pumping stations are under-powered :—

Name of Station.	Pumping capacity in Gallons per hour.		Approximate ratio of required capacity to present capacity.	Remarks.
	Existing.	Required.		
Mylapore, South.	...	46,500	...	Proposed new station.
Do. North	26,000	73,500	3 to 1	
Edward Elliott's Road ...	...	32,400	...	Proposed new station.
Ice House Road.	37,000	164,280	4½ to 1	
Gr[illegible]ad ...	...	48,840	...	Proposed new station.
Napier Park ...	...	453,600	...	
Lang's Garden ...	24,000	122,[illegible]40	5 to 1	
DeMellow's Road or Purasawakkum	33,000	418,800	13 to 1	
Law College ...	50,000	45,000	1 to 1	Recently installed plant.
Rayapuram ...	240,000	230,000	1 to 1	

This table shows very clearly that, with the exception of the new Law College and Rayapuram Stations, the capacity of the existing pumping plant is totally inadequate. It is insufficient even for the present quantity of sewage that comes to the pumping station, as is proved by that fact that all the sewers

in Madras, except some of those in Mylapore area, are surcharged for some hours every day. When the new water-supply has been introduced, and when the sewer system has been completed, the pumps will be ridiculously too small and on this account it is an urgent matter to replace them as soon as possible. Furthermore, in most of the stations, the engines and pumps are in bad running order, and by the time that they can be replaced by new pumps of suitable design, most of them will be quite worn out.

Types of new pumps proposed.

126. The pumps proposed are of two general types—(1) Steam Driven Plunger Pumps, (2) Centrifugal Pumps. The steam engines will be used at the stations where a head with a considerable percentage variation is to be anticipated; that is, where the pumps discharge into a long cast-iron pumping main.

Thus it is that steam engines and pumps are recommended for North Mylapore, Ice House Road and Napier Park stations, these being the three stations which deliver into the existing pumping main 9 miles long. Where the relatively constant heads can be obtained Centrifugal Pumps will be employed. These Centrifugal Pumps may be driven by Oil Engines or Electric Motors according to the quantity to be pumped and according to the proximity of the station to an electric cable from which power may be obtained. Pumps of this description are proposed for South Mylapore, Edward Elliott's Road, Graeme's Road, Lang's Gardens and Purasawakkum. In the case of Edward Elliott's Road and possibly Graeme's Road and South Mylapore, the Centrifugal Pump and its oil or electric motor may be replaced by Ejectors. This will largely depend on whether it is possible to obtain a satisfactory self-contained Ejector driven by compressed air or a head of water generated at the station itself. There are such Ejectors in existence, but up to the present they have not proved to be economical. The writer has himself been at work on a pump of this type, but since he came to Madras he has had no leisure to devote to its development. Should a satisfactory Ejector be obtainable, it would be of great value in Madras for small sewage pumping stations. As the cost of upkeep and establishment charges would be considerably less than with any type of pump now available.

Humphrey pump.

127. A new type of pump which is expected to be very economical in upkeep is the Humphrey pump in which the liquid is forced out by the force of explosion of a mixture of gas and air pressing on the liquid without the intervention of a piston, crank, or other mechanical device. One such pump is now being erected at the Tondiarpet Sewage Farm, and it is possible that this type may be found suitable for the Purasawakkum Pumping Station, and, perhaps, some other stations. If so, it will be adopted.

Thus it will be seen that the plant now proposed will not necessarily be adopted, but will depend upon developments that may take place between the submission of this report and the calling of tenders for the plant. Full particulars of the duty which the proposed plant would have to perform, including the quantity of sewage to be pumped, the head against which it has to pump, the horse power required and the number of units proposed are set out in the following table:—

Table showing quantities to be pumped and the Pumping Power required in 1936.

here the hydraulic gradient level at the beginning of any Pumping Main is below ground level, the working head is calculated from ground level to the king level in Pumping Station Suction Wells.

ue of tion.	Hydraulic Gradient Level at beginning of Pumping Main. Max. rate of flow.	Mean rate of flow.	Minimum rate of flow.	Ground Level at beginning of Pumping Main.	Working Level in Pumping Station Suction Well.	Working Head in feet for Max. rate of flow.	Mean rate of flow.	Minimum rate of flow.	Maximum quantity to be lifted by Pumps in galls. per minute.	Water H. P. at maximum rate.	Type of Plant proposed.	Approximate Pump efficiency.	Nett B. H. P. required.	Allow for stand-bye.	Total B.H.P. to be provided.	Number of Pumping units proposed
lapore.	33·30	24·50	23·40	26·00	14·50	18·80	11·50	11·50	775	4·5	Oil-engines and Centrifugal Pumps.	15%	10	½	15	3 No.
th Mylapore.	150·30	42·30	28·95	26·00	14·00	136·30	28·30	14·95	1,225	50	Steam driven Plunger Pumps.	75%	66	½	100	3 No.
Edward Elliott's Road ...					14·00	13·50	13·50	13·50	540	2·2	Self-contained electrically driven Compressor and Ejector or Oil-engines and Centrifugals.	40%	5·5	In duplicate.	11	2 No.
Ice House Road ...	122·70	38·30	27·95	31·50	14·00	108·70	24·30	17·50	2,738	90	Steam driven Plunger Pumps.	80%	112	⅓	150	4 No.
					Low level suction trough.											
pier Park	98·40	39·50	32·40	29·00	13·00	85·40	26·50	19·40	3,597	93						
					High level suction trough.						185					
					22·00	76·40	17·50	10·40	3,963	92	Steam driven Plunger Pumps.	85%	218	⅓	290	4 No.
...	32·00	25·55	24·75	32·00	14·00	18·00	18·00	18·00	814	4·5	Oil-engines and Centrifugal Pumps.	45%	10	½	15	3 No.
s ardens...	25·00	23·70	23·55	28·00	14·00	14·00	14·00	14·00	2,039	8·5	Oil-engines and Centrifugal Pumps.	50%	17	½	26	3 No.
urasa-wakkum ...	42·90	31·80	30·50	27·00	11·50	31·40	20·30	19·00	6,980	67	Oil-engines and Centrifugal Pumps.	60%	112	⅓	150	4 No.

Pumping Mains (Drawings Nos. 2 and 24 to 35).

Table of Pumping Mains.

128. As will be seen from the General Drawing No. 2, there are in all six principal Pumping Mains exclusive of the minor pumping mains from Ice House Road, Napier Park and A, B and C Pumping Stations, Tondiarpet. The following table shows the hydraulic gradients and velocities in the proposed pumping mains :—

Table showing Lengths, Diameters, Hydraulic Gradients and Flows and Velocities in proposed Pumping Mains.

Notes—(*a*) The hydraulic gradients and velocities shown thus—1 in 1,200 are for clean pipes and are not used for calculating the working head but are given for information. The figures used in the calculations allow for the pipes not being quite clean and smooth and are shown below the clean pipe fi

Pumping Station.	Flow in Pumping Main in cubic ft. per minute.			Size of Pumping Main diameter.	Hydraulic Gradients for			Velocity in feet per second for			Length of Pumping Main in feet.	Hydraulic gradient level at discharge end of Pumping Main.	Hydraulic rise in feet in Length of Main		
	Max. rate of flow.	Mean rate of flow.	Minimum rate of flow.		Max. rate of flow.	Mean rate of flow.	Minimum rate of flow.	Max. rate of flow.	Mean rate of flow.	Minimum rate of flow.			Max. rate of flow.	Mean rate of flow.	Minimum rate of flow.
Mylapore, South (new Pumping Main) ...	124	46·50	23·25	12 ins.	1 in 350	1 in 2,480	1 in 9,920	2·60	0·98	0·49	3,600 ft.	23·00	10·30	1·50	0·4
Mylapore, North (existing Pumping Main, part of Main No. 1).	196	73·50	36·75	12 ,,	~~1 in 125~~ 1 in 115	~~1 in 990~~ 1 in 820	~~1 in 3,960~~ 1 in 3,280	~~4·40~~ 4·60	~~1·60~~ 1·70	~~0·78~~ 0·85	3,440 ft.		29·10	4·20	1·05
	196	73·50	36·75	18 ,,	~~1 in 1,200~~ 1 in 1,050	~~1 in 8,500~~ 1 in 7,450	~~1 in 34,000~~ 1 in 29,800	~~1·90~~ 2·00	~~0·70~~ 0·75	~~0·35~~ 0·38	1,410 ft.		1·30	0·20	0·05
	634	237·75	118·87	18 ,,	~~1 in 115~~ 1 in 105	~~1 in 820~~ 1 in 750	~~1 in 3,280~~ 1 in 3,000	~~6·00~~ 6·30	~~2·20~~ 2·30	~~1·10~~ 1·20	10,020 ft.	24·50	95·40	13·40	3·35
Edward Elliott's Road (new Pumping Main No. 3)	86	32·25	16·12	12 ,,	1 in 720	1 in 5,300	1 in 21,200	1·80	0·68	0·34	1,230 ft	25·00	1·70	0·2	·05
Ice House Road (existing Pumping Main, part of Main No. 1).	438	164·25	82·12	18 ,,	~~1 in 245~~ 1 in 220	~~1 in 1,750~~ 1 in 1,550	~~1 in 7,000~~ 1 in 6,200	~~4·10~~ 4·30	~~1·50~~ 1·60	~~0·75~~ 0·80	600 ft.		2·		
	634	237·75	118·87	18 ,,	~~1 in 115~~ 1 in 105	~~1 in 820~~ 1 in 750	~~1 in 3,280~~ 1 in 3,000	~~6·00~~ 6·30	~~2·20~~ 2·30	~~1·10~~ 1·15	10,020 ft.	24·50	95·40	13·40	3
Napier Park (existing Pumping Main, part of Main No. 1) ...	1209	450·38	225·18	27 ,,	~~1 in 280~~ 1 in 250	~~1 in 2,000~~ 1 in 1,800	1 in 8,000 1 in 7,300	~~5·00~~ 5·30	~~1·90~~ 2·00	~~0·95~~ 1·00	10,560 ft.		42·20	5·80	1·50
	1209	450·38	225·18	30 ,,	~~1 in 490~~ 1 in 440	~~1 in 3,500~~ 1 in 3,100	~~1 in 14,000~~ 1 in 12,400	~~4·10~~ 4·30	~~1·50~~ 1·60	~~0·75~~ 0·80	9,910 ft.		22·50	3·20	0·
	1209	450·38	225·18	33 ,,	~~1 in 810~~ 1 in 730	~~1 in 5,750~~ 1 in 5,180	~~1 in 23,000~~ 1 in 20,720	~~3·40~~ 3·60	~~1·28~~ 1·40	~~0·64~~ 0·70	2,670 ft.	30·00	3·70	0·50	
Greame's Road (new Pumping Main No. 4).	130	48·75	24·38	12 ,,	1 in 320	1 in 2,250	1 in 9,000	2·70	1·00	0·50	2,380 ft.	24·50	7·50	1·05	
Lang's Gardens (new Pumping Main No. 5).	326	122·25	61·12	21 ,,	1 in 1,000	1 in 7,100	1 in 28,400	2·30	0·90	0·45	1,500 ft.	23·50	1·50	0·20	0·0
Purasawakkum (new Pumping Main No. 6).	1116	418·50	209·25	36 ,,	1 in 1,500	1 in 10,650	1 in 42,600	2·60	0·98	0·49	14,100 ft.		9·40	1·30	0
	1116	418·50	209·25	33 ,,	1 in 950	1 in 6,750	1 in 27 000	3·10	1·18	0·59	3,300 ft.	30·00	3·50	0·50	0
Tondiarpet "D" ...	These areas are not sufficiently developed for accurate estimates to be made.														
Tondiarpet "E" ...															

The pumping mains from Law College and Rayapuram and from A, B and C Stations in Tondiarpet, have been dealt with in previous reports of the writer to which reference may be made, if any particulars are required.

Air valves will be provided at all summits, and wash-outs at all depressions. These are not shown in every case on the plans and sections, but are included in the estimates.

The mains have been designed of such a size as will secure a self-cleansing velocity at the maximum rate of flow. The Edward Elliott's Road Pumping Station Main is rather too large to ensure a self-cleansing velocity. This district may however, grow more rapidly than allowed for, and it is considered advisable to provide a 12-inch main in preference to the 10-inch which would be theoretically large enough.

In this connection it is interesting to note that the existing pumping main has gradually silted up until the waterway has been reduced to such an extent that, with the maximum rate of pumping, the velocity of the sewage is 2½ feet per second. This is therefore about the minimum velocity required to keep the main clean.

Pumping Main No. 1 (Drawings Nos. 2, 6 and 7).

The Cast-iron Main No. 1 is the existing pumping main from Mylapore the Sewage Farm. It will be retained to deal with the drainage of the hern area, including Mylapore, Triplicane and Nungambakkum. The length his main is 41,440 feet.

The objections to long pumping mains have been explained in Chapter VI, paragraph 90. The faults of this main are clearly brought out by the experiments described in Chapter XVIII. In a completely new scheme the writer would certainly not have proposed such a main. In view of its existence, it is advisable to utilise it to the greatest advantage.

Drawing No. 2 shows the line of the main, and Drawing No. 6 shows the section of the main and also the hydraulic gradients, as determined from an experiment carried out on the 19th October, 1912. Drawing No. 7 shows the hydraulic gradients and quantities for various flows. The green line shows the flows under the present conditions as determined on the 19th October, 1912. The pumps were then working at their maximum capacity and it is interesting to note that the total discharge was at the rate of 19 gallons per head per day. The full red lines show the conditions, as they will be in the proposed scheme when discharging sewage at the rate of 66⅔ gallons per head per day. If the pumping main were retained as one continuous pipe from Mylapore to the Farm the pressure at the extreme south would be some 220 feet. To obviate the danger due this excessive pressure, it is proposed to cut the pipe at Napier Park Station and re-pump here. This will reduce the pressure at Mylapore to about 140 feet. This reduction in pressure is shown on Drawing No. 7 and Plate 24 by the vertical distance between the dotted red line AA and the full red line BB.

The section of the main shown on Drawing No. 7 shows how it is proposed to be cut some 4,700 feet from the Sewage Farm, and the sewage diverted into Gravitation Main No. 1 through which it will flow straight to the Farm. By this means the pressure at the pumping stations will be further

reduced by some 19 feet, and it is hoped that the existing pumps, which are greatly overworked, will then be able to render much more effective service.

Pumping Main No. 2.

Pumping Main No. 2 consists of a 16-inch cast-iron pipe from Law College to Rayapuram Pumping Station and a 36-inch pipe from the Rayapuram Station to the head of Gravitation Main No. 2. This work was completed during 1912 and the mains are now in use. Full details have been given in previous reports of the writer, and need not be repeated here. It is sufficient to say that the pumps and mains are working quite satisfactorily, and that the pumps are far more efficient than any others in Madras.

Pumping Main No. 3 (Drawings Nos. 24 & 25).

Pumping Main No. 3 starts from the Edward Elliott's Road Pumping Station and delivers into the head of the Gravitation Main No. 3 leading to Ice House Road Pumping St[illegible] is a 12-inch diameter cast-iron pipe 1,230 feet long. If the population of [illegible]es not increase more rapidly than is anticipated, it is probable that a 10[illegible] may be substituted. This point will be settled when details of the drain[illegible] the Edward Elliott's Road come to be worked out. Gravitation Main No. 3 will be of great value in extending the area which can be drained to the Ice House Road Pumping Station. It is probable, however, that its gradient may be improved, if the pumping main is extended. Its present length is 1,100 feet, but in all probability, when the scheme comes to be worked out in greater detail, it may be made some 500 feet longer. As has been remarked in dealing with the drainage of the Edward Elliott's Road area, it would be useless to work out minute details at the present time, as this area is likely to be one of the last to be taken in hand, for the reason that it is sparsely populated and its sanitary conditions compare favourably with the more densely populated areas.

Pumping Main No. 4 (Drawings Nos. 26 & 27).

Pumping Main No. 4 starts from the Graeme's Road Pumping Station and delivers into the head of Gravitation Main No. 4 leading to Lang's Garden Pumping Station. It is a 12-inch diameter cast-iron pipe 2,380 feet long. After leaving the pumping station, it is laid under the River Cooum. This work should present no difficulty if carried out in dry weather. At the lowest point a wash-out is provided, delivering into the collecting well of the Graeme's Road Pumping Station. It will also have a branch delivering into the Cooum.

Pumping Main No. 5 (Drawings Nos. 28 & 29).

Pumping Main No. 5 starts at Lang's Garden Pumping Station and delivers into the head of the long Gravitation Main No. 5 passing through Periamet and Purasawakkum to [illegible]urasawakkum Pumping Station. It is a 21-inch diameter cast-iron pipe 1,500 feet long and is provided with a wash-out at its lowest point. An air valve is not required on this main, as one summit is at the junction of the gravitation main and the other summit at the pumping station.

Pumping Main No. 6 (Drawings Nos. 30 to 38).

Pumping Main No. 6 begins at the Purasawakkum Pumping Station and continues northwards across the Madras and Southern Mahratta Railway, where it turns again northwards following the East Coast Railway till it turns eastwards to join the Gravitation Main No. 1. This main has a total length of

17,400 feet and will be composed of 14,100 feet of new 36-inch pipes and 3,300 feet of old 33-inch pipes which have been taken up at the Sewage Farm and which are now available for use.

Between chainage 2,000 and 2,700 feet, the main will cross the Otari Nullah. It will be taken over this stream on the western side of the bridge. Between chainage 3,000 and 3,900 feet, it will cross under the railway. No special construction will be required at this point, as it will follow the road. Between chainage 7,400 and 7,600 feet, the main will cross underneath the Buckingham Canal. Here some heavy work may be necessary in order to keep the water-way open. Between chainage 14,800 and 14,900 feet, the East Coast Railway will be crossed. Detail arrangements for this crossing will be made with the Railway Company who are likely to require the pipe to be laid in a culvert, in order that no damage may be done in case of accident.

The main joins the Gravitation Sewer No. 1 which at this point will be enlarged from a 3 feet 6 inches brick sewer to a 4 feet 6 inches diameter brick sewer.

Brick Sewer and Gravitation Mains and Overflows.

Brick Sewers.

129. For sewers up to 21 inches in diameter, stoneware pipes will, as a rule, be employed, except in a few cases where bad ground and large volumes of water render it desirable, to use cast-iron pipes. For sewers above 21 inches in diameter, brickwork in most cases will be resorted to, cast-iron pipes will be substituted only in those cases where difficulties are anticipated which would render brick-sewers impracticable. The reason why brick sewers will be used wherever practicable is that they are much cheaper in Madras than cast-iron pipes for all sizes above 24 inches and can also be economically used in place of stoneware pipes above that size.

Brick sewers and gravitation mains will be constructed of brickwork on a concrete foundation. The bricks will be hard, well burnt and non-absorbent. Where the work is above the sub-soil water level, or where only a small quantity of water is met with, both the concrete and brickwork will be constructed in the "combination mortar" which has been used so successfully not only on the drainage works already carried out but to a greater extent on the water-works. This mortar enables a saving to be made of Rs. 20 to Rs. 25 per 100 cubic feet as compared with cement mortar composed of 1 cement to 3 sand. Briquettes of this combination mortar in long period tests show a strength equal to that of Portland cement mortar 1 cement to 3 sand. Where there is running water, Portland cement concrete will be used, the strength being varied according to circumstances, a 1-3-6 mixture being used ordinarily.

Gravitation Sewer to Napier Park Pumping Station (Drawing Nos. 39 & 40).

130. A brick-sewer 2 feet 3 inches in diameter and 1,060 feet long will be laid to connect the existing cast-iron pumping main to the Napier Park Pumping Station, so as to reduce the pressure on the south-end of the Pumping Main No. 1 by breaking the lift between Mylapore and the Sewage Farm and re-pumping at the Napier Park Station (*vide* page 70).

131. *Gravitation Main No.* 1 begins at the end of Pumping Main No. 1 (the existing Cast-iron Pumping Main) from the Southern Division and delivers into Gravitation Main No. 2. For the first 60 feet, it is 3 feet in diameter and then enlarges into a 4 feet 6 inches brick sewer where it is joined by the Pumping Main No. 6 just at the north of Tondiarpet B Pumping Station on Tiruvottiyur High Road. It runs along the Tiruvottiyur High Road as far as Kuppam Road, then turns to the east and runs down to Surianarayana Chetty Street, where it joins the existing 5 feet 6 inches brick sewer now under construction and known as Gravitation Main No. 2.

Gravitation Main No. 1 (Drawings Nos. 42 to 45).

Drawing No. 45 shows details of the Bellmouth chamber and manholes.

132. *Gravitation Main No.* 5 beg[illegible]at Pantheon Road at the end of the Pumping Main No. 2 from the Lang's Ga[illegible] Pumping Station and runs to the proposed new Pumping Station at Purasaw[illegible]um, passing along Ponniammen Covil Street, Sc[illegible]n Church Road, Rundall's Road, Jeremiah's Road, Vedavinayagar Road and [illegible]erambur Barracks Road to the proposed new station at the junction of Perambur Barracks Road and Farren's Road. It is a 2 feet 3 inches brick sewer laid at a gradient of 1 in 1,000 to chainage 5,500 feet, at which point it is enlarged to a 2 feet 6 inches diameter sewer laid at a gradient of 1 in 1,150 to chainage 6,900 feet, where it is again enlarged this time to a 2 feet 9 inches diameter brick sewer laid at a gradient of 1 in 1,300 as far as chainage 10,000, where the invert has to be dropped, in order to intercept the cast-iron sewer from Sydenham's Road. At this point it is enlarged to a 3 feet 6 inches diameter iron pipe, and the level becomes some 12 feet below sea level.

Gravitation Main No. 5 (Drawings Nos. 46 to 55). Manholes.

This Gravitation Main No. 5 is very important as it enables the Purasawakkum drai[illegible]ge area to be enlarged considerably. Details of the various manholes and other works are given on Drawings Nos. 46 to 55.

On Drawing No. 48 is shown a typical drop manhole into which two rider sewers enter. It should be mentioned that wherever the mains are deep, rider sewers will be employed and will be connected to the mains at convenient points by means of drop manholes.

On Drawing No. 51 is shown the detail of Manhole No. 117, where the 21-inch pipe brings in the sewage from Ritherdon Road and Purasawakkum High Road and the following sewers join :—

(1) A 9-inch rider sewer from Jeremiah Road.
(2) A 12-inch pipe sewer from Ritherdon Road.
(3) An 18-inch pipe from Purasawakkum High Road.
(4) A 9-inch pipe from Hunter's Road.

Drawing No. 55 shows details of the connection between the 27-inch cast-iron pipe coming from Sydenham's Road and the 2 feet 9 inches brick sewer running down Perambur Barracks Road which join together and continue as 42-inch cast-iron pipe to the pumping station.

133 As stated elsewhere in the report, it is proposed to abandon the existing DeMellow's Road Pumping Station and to convey the sewage now flowing to it to the proposed Purasawakkum Pumping Station. As a number of sewers have been laid so as to gravitate to the DeMellow's Road Station, an inter-

Sydenham's Road intercepting sewer (Drawings Nos. 56 to 60).

cepting sewer will be laid to carry the sewage to the Purasawakkum Station. This intercepting sewer will be deep for the whole of its length, and it has, therefore, been decided to lay it with cast-iron pipes. It will begin as a 24-inch cast-iron pipe connecting with the existing 18-inch intercepting sewer, which is really too small, but it will be retained so long as it can work satisfactorily.

At chainage 9,850 the new sewer will receive a sewer running down Suttanna Naicken Street. From this point it will be enlarged to a 27-inch diameter cast-iron pipe laid at a gradient of 1 in 1,200 until it reaches Gantz Road, where it will pick up the 21-inch sewer from that road, it will then be 30 inches diameter until it joins Gravitation Main No. 5 and continue to Purasawakkum Pumping Station in a 42-inch pipe. This Sydenham's Road intercepting sewer will be laid at a considerable depth, and before deciding whether it was feasible to lay it as proposed, trial holes were got out which proved that the subsoil water is not likely to be encountered in very large volumes. At the same time, the work will be slow and expensive, but the cost will be well repaid, as the sewer will make it possible to dispense with an extra pumping station at DeMellow's Road.

Storm-water overflows (Drawings Nos. 41 and 61 to 66).

134. Storm-water overflows to the sewage system will be provided wherever practicable, and every pumping station will be provided with an overflow. The site plans of the pumping stations show the positions of the overflows for those stations and they need not be described in detail. In the case of larger overflows, special drawings have been prepared.

Overflows into Madras Harbour (Drawings Nos. 61 to 64-A).

135. There are at present a number of overflows into the Madras Harbour for the purpose of relieving the sewer which runs down First Line Beach. It is proposed to intercept these overflows by a large brick-sewer starting at the south end of First Line Beach and running to the north of the Harbour, where it will discharge at the outer angle of the north arm. This sewer is described in Chapter XIX, dealing with surface water drainage. It is anticipated that this work will be carried out by the Special Works Department, but the cost should be borne by the Port Trust because the work is for the benefit of the Harbour.

Napier Park Pumping Station Overflow (Drawing No. 41).

136. The overflow for the Napier Park Pumping Station is shown on Drawing No. 41. It is a brick culvert 3 feet in diameter, laid at a gradient of 1 in 1,000. It has a total length of 760 feet and discharges into an existing open masonry drain leading into the Cooum.

Purasawakkum Pumping Station Overflow (Drawings Nos. 65 and 66).

137. Drawing No. 65 shows the overflow proposed for the Purasawakkum Pumping Station. This is a U-shaped drain 3 feet wide and 3 feet deep, with a flat top, discharging into the Otari Nullah.

Lang's Garden Pumping Station Overflow (Drawing No. 67).

138. The storm-water overflow for Lang's Garden Pumping Station, 820 feet long, consists of 2 feet 3 inches diameter brick-sewer, laid at a gradient of 1 in 700 and discharging into the River Cooum. It is provided with a flap door at the outlet and another flap door at the overflow chamber. These are required to prevent the Cooum obtaining access to the pumping station in times of flood.

Dealing with Sewage.

Proposed Sewage Farm Extension (Drawings Nos. 69 to 81).

139. To deal with the larger quantity of sewage which will enter the drainage system after the new water-supply has been introduced, and after a complete system of sewers has been laid, it is proposed that the existing Sewage Farm should be extended northwards. Before preparing a design for disposing of sewage on these lines, the question of a new Sewage Farm at Vyasarpady to the north-west of Madras was carefully considered. The advantages of this site are—

(1) That there is at Vyasarpady a large area of land which is not subject to erosion by sea.

(2) That there are very few houses in this direction.

(3) That throughout the year there is, in Madras, practically never any wind from the north-west, and, therefore a Farm in this position would produce no nuisance.

(4) That there would be an economy in the main required to convey the sewage from the western area of Madras, as Purasawakkum is considerably nearer to Vyasarpady than to the existing Farm.

If a Farm in this position had been recommended, it was intended that the existing Farm should be retained to deal with the sewage from the south and north of Madras and the new Farm from the west of Madras. The disadvantages of a Farm in this position are—

(1) That it would mean a separate establishment to look after it.

(2) That a large area of land would be required

(3) There is no suitable overflow channel available.

It was the second reason which decided the writer to recommend the extension to the north of the existing Farm. Trial holes were sunk in the Vyasarpady area and it was found that the ground was not porous, but consisted of a mixture of fine sand and clay. With soil of this nature a very large area would be required to take the whole of the sewage. From a farming point of view, this might be an advantage, inasmuch as a given quantity of sewage would irrigate a larger area; but the principal object the Corporation have in view is to dispose of the sewage in an inoffensive manner. From this point of view land, which will take a large quantity of sewage per unit area, is desirable. Such land is to be found along the seashore to the north of the existing Farm.

General plan of Sewage Farm Extension (Drawing No. 69).

140. The general scheme proposed for the irrigation of the Sewage Farm extension is shown on Drawing No. 69. From this drawing it will be seen that it is proposed to extend the open channel which supplies the existing Farm and to carry it north along the western margin of the proposed extension and then to turn eastwards along the northern margin ending with an outlet into the sea which would serve as an overflow during the monsoon and during such other times as the quantity of sewage was greater than the Farm would take.

The total length of the new channel is 9,800 feet. At every 450 feet along its length are valves through which the sewage may be turned into the distribution mains consisting of 15-inch stoneware pipes laid underground in parallel lines at right angles to the sea. At every 200 feet along these

mains will be constructed valve chambers at which the sewage can be turned into the open channels running at right angles to the distribution mains. The open channels will be lined with 15-inch stoneware channels and slightly raised above the ground surface, to allow the overflowing liquid to flow over the ground. The principle of the proposed irrigation system is very similar to that which has already been installed in the existing Sewage Farm and which has proved quite satisfactory.

Levels of ground.

141. Levels have been taken all over the area. They are shown on Drawing No. 69 as contours plotted every two feet vertically. A glance at the Drawing will show that the slope of the ground is suitable for irrigation, there being a total fall of about 6 feet from the western margin to the eastern margin. There are a number of small ponds which will of course have to be filled up. There are also two fishermen's villages or Kuppams which will have to be removed and accommodation for the fishermen found elsewhere.

Open Channel (Drawings Nos. 70 to 74).

Arched section.

142. Drawings Nos. 70 to 74 show the enlarged plans and sections of the channel. At the commencement there is a depression over which the channel will be carried on five brick arches springing from brick piers. An enlargement of this section of the channel is shown on Drawing No. 75 from which it will be seen that the arches consist of two rings of brickwork. They have a span of 6 feet and a rise of 18 inches. The foundations are well spread to keep the pressure low as owing to the high level of the sub-soil water, it is very expensive to lay deep foundations.

Section above ground (Drawing No. 70).

143. Drawing No. 70 shows a typical cross section of the open channel which will be used everywhere where the invert is higher than one foot below ground level, the only exception being in the case of arched section already referred to.

It will be seen that the channel consists of two brick walls on a shallow foundation. The floor consisting of reinforced concrete will rest on sand filling, and will be covered with a brick invert. The whole of the channel will be coated internally with $\frac{5}{8}$-inch of cement plaster and externally with $\frac{3}{8}$-inch of combination mortar plaster.

Typical cross section below ground (Drawing No. 71).

144. Drawing No. 71 shows a typical cross section where the invert is one foot or more below ground level. In this case, the channel consists of concrete floor with brick invert and brick side walls. Throughout the work, combination mortar will be used everywhere except for the reinforced concrete and for the internal plastering of the channel where Portland cement mortar will be employed.

Road Bridge (Drawing No. 76).

145. Drawing No. 76 shows details of the proposed road bridge over the open channel. The floor of the bridge will consist of rolled steel beams with a concrete filling reinforced with steel rods.

Valves (Drawing No. 77).

146. Drawing No. 77 shows the arrangement proposed for letting the sewage out of the channel into the distribution mains. It will be seen that for the main outlets it is intended to use 12-inch stoneware pipes (governed by a 12-inch valve) leading from the invert of the channel. For the intermediate valves, similar 9-inch pipes will be employed.

Outlet to sea.

147. Where the channel ends at the sea the invert will be stepped gradually down and will terminate in a pitched open channel consisting of concrete and granite stone pitching grouted with cement mortar, in order that the rush of water may not be great.

Septic Tanks (Drawings Nos. 79 to 81).

148. When the Water Carriage System has been more completely introduced and the solids are all taken to the sewers, it may be that the sewage will be stronger and that some sort of preliminary treatment may be desirable before it is turned over the land. Some such treatment would certainly enable a given area of land to deal with more sewage, if it were properly underdrained. In fact, if necessary, this area of land might be made more of the nature of a filter than of a farm. To meet the possibility of [illegible] contingencies, designs for septic tanks have been prepared in which the sewage may be treated and sludge removed, so that the effluent will contain a comparatively small amount of solid matter and could be dealt with on a small area. These septic tanks are shown on Drawings Nos. 79 to 81.

Drawing No. 79 is a general plan of the tanks from which it will be seen that the sewage would be taken to the western end of each tank from the channel and discharged at the eastern end, the effluent channel constructed along the eastern and northern sides of the tanks conveying the effluent back into the open channel.

The total area of the tanks shown is 206,400 square feet (516 feet by 400 feet).

There are five tanks, each 400 feet long by 100 feet wide and 7 feet deep at the walls with a fall of one foot towards the sludge channels. The inlet to the tanks is direct from the open channel through a cast-iron penstock working in a frame fixed to the channel wall. The bottoms of the tanks are sloped to two sludge drains each provided with eight sludge pipes, so that in effect, the floor of the each septic tank is divided into sixteen sections, each section being provided with a sludge outlet.

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Details of the sludge valve chamber are shown on Drawing No. 80. The details of the tank inlets and of the gauging basin are shown on Drawing No. 81.

Should it be decided that some sort of tank is necessary, the matter will be carefully gone into again. The sewage will be analysed and the tanks specially designed to treat it. It is quite likely in this case, that a design somewhat different from that now submitted will be adopted. In fact the writer is in favour of hydrolytic tanks of the Travis or similar type. The necessity for having the tanks at all has not yet been determined, and the present design is considered to be sufficient for the purpose of estimates.

CHAPTER VIII.

EXECUTION OF WORKS.

Order of Execution—Staff—Plant.

Order of Execution.—149. Three Main Divisions can be executed independently. 150. Purasawakkum Pumping Station and its area. 151. Napier Park Pumping Station and its area. 152. Ice House Road Pumping Station and its area. 153. Works recommended to be put in hand at once. 154. Agency for executing work. 155. Division of work to be executed immediately. 156. Materials and machinery contracts.

Staff.—157. Staff required. 158. Necessity for contingent staff. 159. Purchase of materials. 160. Assistance rendered by President.

Plant.—161. Pumps in stock. 162. New pumps required. 163. Derrick crane. 164. Timber.

Stores, Sheds, Offices, etc., on site of Work.—165. Stores. 166. Large store sheds. 167. Small store sheds for inflammable materials. 168. Supervisors' offices. 169. Overseers' offices. 170. Telephones. 171. Theodolites. 172. Levels.

Order of Execution.

149. In considering the order of carrying out the work, it may be again mentioned here that in the new drainage scheme there are three main drainage divisions, namely, the North, South and West, and shown on Plate IV. These are independent and, as far as possible, all the urgent work in each division should be carried on simultaneously. This, however, is impossible for two reasons :—

Three Main Divisions can be executed independently.

(1) the staff in the Special Works Department is insufficient to get out detail designs, contract forms and supervise the execution of the work, and

(2) the amount and the nature of the work involved will be beyond the capabilities of the labour (both skilled and unskilled) available in Madras.

150. It is therefore necessary to consider the absolute order of urgency in respect of the three main divisions. There is no doubt that the most urgent works are the pumping stations for Purasawakkum, Napier Park and Ice House Road. The most insanitary area in Madras, omitting Tondiarpet (the drainage of which is practically complete), is the Purasawakkum area. Before this can be drained, it is necessary to construct the Purasawakkum Station, lay the pumping main from that station to the Sewage Farm and construct the large deep gravitation main which is shown running from the south to the north of that area.

Purasawakkum Pumping Station and its area.

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151. The next most important work is the construction of a new pumping station for Napier Park. This is necessary for the two following reasons :—

Napier Park Pumping Station and its area.

(1) The existing pumping plant is incapable of raising all the sewage that comes to it (and there is a large quantity of sewage from Triplicane and Chintadripet which should be dealt with at this station).

(2) That by relieving the pressure against which the Ice House Road pumps have to work, the quantity of sewage which these pumps can deal with would be considerably increased, a consummation which is most desirable for the reason that the Ice House Road pumps are at the present time unable to deal with the sewage that comes to them. The sewer system of the area draining to the Napier Park Pumping Station should be carried out as early as possible, as, next to Purasawakkum, this is probably the most insanitary area which has still to be dealt with in Madras.

Ice House Road Pumping Station and its area.

152. The existing pumps at the Ice House Road Station are not able to deal with the whole of the sewage that comes to them. The sewers in this area are often very badly surcharged. The consequence is, that the sewers become silted up to such an extent, that it is only with considerable difficulty that the cleaning staff is able to keep them in working order. The capacities of the pumps at the Ice House Road Pumping Station may, however, be considerably increased by the construction of the Napier Park Pumping Station, as already mentioned in the last paragraph.

The sewers in the Ice House Road area require relaying. As already stated, some of them are silted up badly, but it would be well to wait until the pumping station has been constructed before dealing with the drains, as it is believed that the installation of new pumping machinery capable of dealing with all the sewage that comes to it, will greatly improve the sewers by keeping a good flow through them. This combined with the exclusion of silt and storm-water may render the majority of the sewers usable without relaying.

Works recommended to be put in hand at once.

153. The works that are now recommended to be put in hand at once are—

(1) The construction of the new Purasawakkum Pumping Station.

(2) The construction of the New Napier Park Pumping Station.

(3) The drainage of the Purasawakkum area including the large Gravitation Main through that area, the cast-iron intercepting sewer from Sydenham's Road, the Pumping Main No 6 and the Gravitation Main No. 1 which will convey the sewage from the Purasawakkum Station to the Sewage Farm.

(4) The laying of underground drains in Georgetown.

The reason why this last work should be put in hand is that adequate pumping plant has already been installed at the Law College and Rayapuram Stations and the laying of underground drains in these areas can be carried out without interfering with the other urgent drainage work. The benefit to be derived from underground drains in this populous area would be very great indeed. Complaints have been made of the smell at the Sewage Farm. The writer from considerable experience of both Georgetown and the Sewage Farm would very much rather live in a bungalow built on the Sewage Farm than in one built amongst the open drains of Georgetown. There is no doubt that the foul gas rising from these open drains must very greatly lower the vitality of those residing in the areas where they exist, and it appears to the writer highly desirable that they should be done away with, and the sewage removed in a cleanly and

inoffensive manner with the least possible delay, as this will undoubtedly result in great improvement in the health of the 160,000 inhabitants of this, the most populous, area of the city.

Agency for executing work.

154. It is recommended that the work should be carried out, as far as possible, by contract, and that this system be adopted for sewer laying and for the superstructures of the pumping stations. Experience has shown that the pumping station foundations, the silt pits, screening wells, pump wells and the machinery foundations are not suited to the contract system. These works are largely below water and are frequently delayed for want of machinery drawings. The great importance and the difficulty of making the work watertight, together with the change of detail and delay which usually occur in these foundation works, render them unsuitable to let by contract. They can best be executed departmentally either directly or by piecework contracts, and this method is recommended.

It is also proposed to have at least one departmental sewer-laying gang, so that, if any contractor is not proceeding with due diligence, the whole or some portion of his work may be taken out of his hands and carried out departmentally. In addition, contracts will be let in India and England for materials and machinery, such as cement, pipes, bricks, manhole covers, ventilators, pumping machinery, etc. These contracts will require an out-door staff consisting of store-keepers, testing overseers and the necessary labour required in counting, testing, sorting, arranging, issuing and carting the materials and machinery.

155. If these recommendations are accepted, then the works that are proposed to be put in hand immediately, *see* paragraph 153, may, for construction purposes, be divided as follows :—

Contract Work.

Sewer Laying.

Rayapuram area	2	contracts.
Law College area	1	contract.
Purasawakkum area	2	contracts.

Pumping and Gravitation Mains, etc.

Pumping main and 4 feet 6 inches sewer from Purasawakkum Pumping Station to the Sewage Farm	2	contracts.
Gravitation sewer through Purasawakkum area.	1	contract.
Intercepting sewer from DeMellow's Road Pumping Station to Purasawakkum Station.	1	,,

Pumping Stations.

For the superstructures of the new Ice House Road, Napier Park and Purasawakkum Pumping Stations—a separate contract for each	3	contracts.
Total...	12	contracts.

Departmental Work.

Sewer laying	...	...	1 gang.
House connection work	...	..	4 gangs.

For underground work, screening chambers, silt pits, pump wells, foundations for buildings and machinery at the following pumping stations including the erection of machinery :—

Ice House Road	...	1 gang.
Napier Park	...	1 „
Purasawakkum	...	1 „
	Total...	8 gangs.

Materials and machinery contracts.

156. In addition there will be a number of contracts for materials, plant and machinery—to be purchased either in India or England—such as—

(1) Temporary oil, steam and hand pumps for trench work.

(2) Portland cement, bricks, stone, sand, lime, etc.

(3) Cast-iron pipes, stoneware pipes, ventilating columns, manhole covers, etc.

(4) Steam engines, oil engines, plunger pumps, centrifugal pumps, venturi meters, pump pressure and sewage level recorders and the like.

The preparation of the contracts and the inspection on delivery and erection, and the large volume of correspondence that is inevitable with work of this magnitude will necessitate the employment of a considerable clerical staff and a number of inspecting overseers.

Staff.

Staff required.

157. The following statements show respectively :—

(1) The *out-door staff* required for the work which is recommended to be put in hand without delay.

(2) The *clerical staff* required for getting out contracts, preparing bills, checking measurements, answering audit objections, keeping accounts and dealing with the voluminous correspondence entailed by such work.

(3) The *drawing office staff* required to prepare the numerous detail drawings that will be required and to make the many fresh surveys, etc., as constructional and other problems arise

If the staff proposed is sanctioned, then all other sanctions for drainage staff and general office staff may be cancelled such of the Tondiarpet and other works which still remain to be completed, when orders are passed on the proposals contained in this report, may be executed by the staff now put forward.

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Out-door

Contract Work.

DESIGNATION.	Sewer Laying Contracts.			Pumping and Gravitation Mains.			Pumping Station Superstructures.	Total for Contract Work.
	Rayapuram area.	Law College area.	Purasawakkum area.	Pumping Main and 4 ft. 6 ins. Sewer from Purasawakkum Pumping Station to the Sewage Farm.	Gravitation Sewer through Purasawakkum area.	Intercepting Sewer from DeMellow's Pumping Station to Purasawakkum Station.	For new Ice House Road, Napier Park and Purasawakkum and erection of machinery.	
	I	II	III	IV	V	VI	VII	VIII
No. of Contracts or Gangs	2	1	2	2	1	1	3	12
Supervisors ...	2	1	2	...	1		1	7
Overseers, 1st Grade ...	2	1	2	...	...	...	2 Machinery erection.	7
,, 2nd ,, ...	2	1	2	1	1	1	2	10
,, 3rd ,, ...	...	...	...	1	1	...		2
Testing Overseers ...	...	...	...	...	..	...		...
Surveyors	4	2	4	...	1	...	The necessary supervision for the superstructures will be provided from the staff employed on the departmental substructures given in Column X.	11
Storekeepers ...	...	...	...	...	...	...		...
Asst. Storekeepers ...	...	...	...	...	...	...		...
Lighting Inspectors ...	2	1	2	...	1	...		6
Pipe-laying Maistries ...	4	2	4	2	1	...		13
Bricklaying ,, ...	2	1	2	1	2	1		9
Time-keepers ...	2	1	2	...	1	...		6
Lascars	18	9	18	2	4	1		52

Staff.

Departmental Work.

Sewer-laying Gang.	House Connection Gangs.	Pumping Stations Sub-structures. Ice House Road, Napier Park, Purasa-wakkum.	Materials and Machinery Contracts, etc. Stores and Testing, etc.	Total for Depart-mental Work.	Grand Total Contracts plus Departmental Work.
IX	X	XI	XII	XIII	XIV
1	4	3	...	8	20
1	..	..	..	1	8
1	...	..	...	4	11
1	..	...	...	1	11
2	4	...	...	6	8
...	...	...	2	2	2
1	...	1	..	2	13
...	...	...	4	4	4
...	...	...	4	4	4
...	4	..	...	4	10
...	4	...	2	6	19
1	4	3	..	8	17
1	4	3	1	9	15
2	4	3	8	17	69

GENERAL IN-DOOR ESTABLISHMENT.

Clerking and Accounting Branch.

No.	Designation.	Salary.
		RS.
1	Head Clerk	80
1	Accountant	70
9	Clerks	25 to 40
1	Motor Driver	40
1	Muchi	10
1	Duffadar	10
4	Peons	8
1	Cycle Peon	9
2	Watchmen	7
1	Sweeper	5
1	Scavenger	4

Drawing Office Branch.

		RS.
1	Supervisor	150—200
2	Draftsmen	60
2	Tracers	25 to 45
1	Clerk	30
2	Peons	8
2	Ferro Printers	9

DRAINAGE SECTION.

IN-DOOR ESTABLISHMENT.

Clerking and Accounting Branch.

No.	Designation.	Salary.
		RS.
1	Accountant	50
5	Clerks	one on 40 one on 35 one on 30 two on 25
2	Duffadars	9
2	Cycle Peons	9
3	Peons	8

Drawing Office Branch.

		Rs.
4	Surveyors	one on 60 three on 50
4	Draftsmen	50 to 70
8	Tracers	25 to 45
8	Lascars (Survey)	8
1	Clerk	30

Drainage Superintendent's Staff.

		Rs.
1	Surveyor	50
1	Draftsman	60
1	Tracer	35
2	Lascars	8
1	Duffadar	9
1	Clerk	30

The following is a summary of the Out-door Staff proposed :—

No.	Designation.	Monthly Salary.	Remarks.
		Rs.	
3	Supervisors	200—250	Including allowances. A satisfactory conveyance must be provided by the officer for getting about the work.
5	Do.	150—200	
11	Overseers, 1st Grade	95—120	
11	Do. 2nd do.	75— 90	Plus Rs. 5 allowance so long as a first-class bicycle is maintained and used on the work.
8	Do. 3rd do.	50— 70	
2	Testing Overseers	50— 70	
13	Surveyors	50— 75	
4	Storekeepers	30— 50	
4	Assistant Storekeepers	20— 30	
10	Lighting Inspectors	25— 35	Including all allowances.
19	Pipe-laying Maistries	25— 40	Do. do.
17	Brick-laying „	20— 40	Do. do.
15	Time-keepers	20— 40	Do. do.
69	Lascars	8	Do. do.
	Contingencies	500	

Note.—The Drainage Superintendent's staff will become part of the permanent establishment under the Corporation Engineer if the writer's proposals are carried out (*see* Chapter IX).

The works for which the above staff is required are considered to involve the largest amount of skilled labour which is reasonably obtainable in Madras and the staff enumerated above is intended to be the maximum which will be employed on the drainage works at any time.

This staff will be engaged only as required. It will be increased as the work increases and decreased as the work decreases. As the most urgent works are finished, the same staff will be utilised in carrying out the next most urgent works and so on. The out-door staff listed above will have charge of the whole of the construction work and will keep records of what is done. The surveyors will be engaged as soon as possible, and will first be employed in establishing bench marks all over Madras and in taking the numerous additional levels and in making the many fresh surveys that are required.

Such supervision as is necessary for the erection of engines, and the maintenance of pumps, cranes and other plant required in carrying out the work, will be provided out of that given in the list.

Necessity for contingent staff.

158. The item of contingencies is required in case any work requires supervision, such as is not provided for in the above staff list. When such a contingency occurs, the necessary supervision may be obtained under this heading until the sanction of the Corporation and Government can be obtained to the creation of a new post.

The necessity for a contingent staff provision has been strongly impressed upon the writer by his experience in carrying out works in Madras. For, if any post is not sanctioned by Government beforehand, the time taken in obtaining sanction is so long as to delay progress very greatly. In this connection the following typical instances may be cited :--

(1) *Lighting Inspector.*—Owing to complaints of sewer trenches in Tondiarpet being dangerous through not being properly lighted and fenced at night by the contractors, the writer recommended that an allowance averaging about Rs. 3½ per month be given to one of the storekeepers. It was an obvious necessity, and the Corporation agreed to the payment. The man started work in March 1912, but up to the present—March 1913 has not received a pie of pay from the Corporation, because the necessary sanctions have not yet been obtained. Some of the money has been due for more than 12 months.

(2) *Mechanical Supervisor*—The Mechanical Engineer has for several years been very busy in supervising the erection, testing, and initial running of new pumping plants—work that none of his subordinates were capable of doing. In the meantime the old overworked pumping plant began to give trouble and the writer on March 26th, 1912, wrote pointing out to the President the urgency of appointing a Mechanical Supervisor who should devote his whole time to the existing pumping plant.

The necessity was indisputable, the Corporation agreed, but owing to some red tape—incomprehensible to the ordinary mind—delay was decreed, and it was not until the President, on February 17th, 1913, cut the tangle and spoilt the red tape, that the appointment was made as from December 1st, 1912. If the matter had been allowed to run the course which was laid down as the only proper one, it would not have been sanctioned yet.

In the case of the Lighting Inspector it would appear that carriage accidents were to be allowed to continue for 12 months or more before anything was done to prevent them.

In the case of the Mechanical Supervisor the pumps might entirely break down and Purasawakkum and other areas be flooded with sewage, provided only red tape was maintained intact.

The writer has to confess that in the first case he paid the man himself rather than let accidents continue. In the second case he put on a Mechanical Supervisor and charged him against Waterworks in order to remove the cause of the just complaints of the residents of certain areas. It makes the writer shudder to think of the number of objections and the volumes of correspondence that will ensue should these words be read by the preservers of the sacred tape!

These two cases support the contention here put forward that the President and Special Engineer should be given some discretion in making appointments urgently required. Hence the item of contingencies, which it is hoped will be sanctioned on the understanding that it may be utilized for cases where there is no time to obtain the numerous separate sanctions which are now required. In drawing up a large scheme it is impossible to think of every individual post that may eventually be found necessary. The design and the method of carrying out the work may be changed to something different from what was in the designer's mind, and, in consequence, staff requirements may be altered.

159. Another point upon which special sanction is required is in the matter of purchasing small quantities of materials required for carrying out the work. When large quantities of materials are required, tenders are always called for and no question is raised. Cases frequently arise, however, when small quantities of materials are urgently required. In such, objections are continually being raised to the purchase of materials from others than the Corporation contractors. The criticising officer states that these purchases should be made from the Corporation contractors through the Municipal Stores. This is an impossibility, and the objections are duly met by the President's orders sanctioning such purchases. But before such orders can be obtained, much time is wasted in looking up previous correspondence and previous replies to similar objections.

When writer first came to Madras, he went into this matter with Mr. Lloyd, the President, and Mr. Griffith the then Corporation Engineer, and it was decided that the Special Engineer should *not* order his materials through the Corporation Stores because it would interfere with the quantities included in the annual contracts prepared by the Corporation Engineer. Since then, small quantities of materials have been purchased as the Special Engineer considered best. Except in urgent cases, he invariably obtains quotations and gives the order to the firm submitting the most favourable tender, that is to say, the lowest price taking into account the quality of materials and date of delivery. For any large order, special tenders are called for. This system has worked quite well and for some years, very few, if any, objections were made. Recently, however, objections have been made in every case and the recoupment of the Special Engineer's imprest money has been delayed to such an extent that in

one case he had to send to the Waterworks as much as Rs. 700 of his own money to meet urgent demands. In view of these objections, it is requested that the Special Engineer be exempted from the rule, which is relied upon to force him to the impossible course of always purchasing materials through the Corporation Stores.

The writer has not been able to understand how it is that such a rule is held to apply to the Special Works Department. Apparently, reliance is placed upon the Corporation Code, although the Special Works Department has been exempted from its operation, for the reason that a code intended to apply to permanent establishments cannot be applied to a temporary department such as the Special Works Department.

Assistance rendered by President.

160. The writer must here express his deep gratitude to the Corporation President, Mr. P. L. Moore, C. I. E., for the great assistance he has always rendered in getting work done. When, in despair at the obstacles placed in the way of progress, the writer has appealed to the President. Mr. Moore has never failed to respond, and in a number of cases when the obstacles have been insuperable, he has not hesitated to cut the entangling meshes of codes and rules. But the writer contends that such appeals to the President should be unnecessary. The time of the Special Engineer is wasted in getting the case into proper form for the President to pass orders on it. The President's time is wasted in going through the papers, codes, rules and previous orders in similar cases. As already stated, the President and Special Engineer should be given discretion in making appointments, and in the purchase of materials.

Plant Required.

Pumps in stock.

161. The small Merryweather pumps at present in use in Tondiarpet are not powerful enough to deal with large quantities of water. They frequently break down, very often at times when they are most urgently required. The cost of running them is excessive and a number of the parts are much worn. It is therefore recommended that all of them be sold by auction.

The other pumps in stock and their conditions are as follows—

One 5-inch Centrifugal pump worked by an 8 H. P. Portable Engine.—This pump is not in good condition and requires new bearings and possibly new vanes The portable engine is in fairly good condition, but it will need thorough overhauling after its work in Tondiarpet is finished.

One 4-inch Centrifugal Pump. No engine for this pump.—This pump is in good order and has recently been overhauled. It is at present at Tondiarpet as a stand-bye in case the 5-inch pump should break down.

Two No. 5 Pulsometer Pumps.—Both in good order (no boilers).

One 4-inch Diaphragm Hand Pump in good order.

The above Centrifugal, Pulsometer and Diaphragm pumps should be retained for the new Main Drainage work.

New pumps required.

162 The following new plant should be obtained as soon as the work is sanctioned :—

One 8 H. P. Portable Engine, steam or oil, to work the Centrifugal Pump at present without an engine.

Two Boilers to work the two No. 5 Pulsometer pumps.

Two Boilers and one No. 7 and one No. 8 Pulsometer pumps.

Three oil or petrol Engines with Pumps direct coupled, mounted on carriages, capable of being easily moved about from place to place. Capacity 200 to 300 gallons per minute.

Three 4-inch Diaphragm Hand Pumps.

Derrick Crane

163. Two Derrick Cranes of 3 to 5 tons lifting capacity are required for raising heavy steel beams, engine parts, etc., at the pumping stations, and for laying the heaviest pipes. Three sets of Shear Legs of 2 to 3 tons lifting capacity are required for cast-iron pipe laying, fixing heavy valves, sluices, etc.

Timber.

164. It being the intention of letting practically all the work out by contract; it will be specified that the contractor supplies the necessary timber for shoring of trenches. A quantity must be kept in stock for departmental work in foundations and other heavy work that is not considered safe to give out on contract, also in case it is found necessary, through contractors' slow progress, to supplement contract work with departmental labor. A sum of Rs. 20,000 should be sufficient to cover cost of timber to be kept in stock.

Stores, Sheds, Offices, etc., on site of Works.

165. A large area of ground will be required within each drainage area to store the stoneware pipes and other materials required in the construction of the works.

Large store-sheds.

166. On each piece of ground referred to in para 165: a corrugated iron shed (at least 100 feet long and 30 feet wide) should be erected to store cement and other materials that have to be kept under cover. A corner of this shed should be partitioned off to form an office for the Storekeeper.

Small store-sheds for inflammable materials.

167. A small shed should be erected near each of the above large sheds to store oils and other inflammable material.

Supervisors' offices.

168. On each section an office should be provided for the Supervisors. It should be large enough to allow the out-door Surveyors to prepare bills and to record on the plans all information as to the construction of the works. The size of the office should be about 15 feet by 10 feet, and it should be fitted with the necessary tables, etc. These offices should be so constructed that they can be easily dismantled and moved from place to place as required. If convenient for the work they should be erected at the stores. If it is found better to have the office at any other place a room or small house could be rented for use as the office.

Overseers' offices.

169. Small portable offices, say 6 feet by 6 feet, should be provided for the Overseers on each contract, and these should be built on wheels, so that they can easily be hauled from place to place. These small offices will be used by the Overseers to keep all plans, books, etc., which are required on the works.

Telephones.

170. Telephones should be installed either at the Stores or at the Supervisors' offices. It is also desirable to instal one at the bungalows of each of the Assistant Engineers.

171. Two Theodolites, complete with all accessories, should be provided—one for use of Surveyors sent out from office and one for out-door works use.

172. Twelve Levels, complete with tripods and staffs, should be provided, for use as follows :—

Two for use of Surveyors sent out from office.
Six for Sewer-laying Contracts.
One for 4 feet 6 inches Sewer and Pumping Main.
One for Intercepting Sewer and Purasawakkum Pumping Station.
One for Gravitation Sewer, Purasawakkum area.
One for Napier Park and Ice House Road Pumping Stations.

CHAPTER IX.

AGENCY FOR CARRYING OUT HOUSE DRAINAGE WORK.

173. Present arrangement. 174. Typical designs have been prepared. 175. Special Works Department should be relieved of detailed House Drainage Work. 176. Procedure that might be adopted. 177. Work from Health Department. 178. Combined Drainage. 179. Staff required.

Present arrangement.

173. At the present time, all house drainage work, latrine construction, drainage of public buildings and the [illegible] supervised by the Special Works Department. On account of the accumulation of this work, Mr. S. Cartledge, an English Sanitary Inspector, was obtained in 1911 to look after this work under the title of Drainage Superintendent. Since then, a considerable amount of work has been completed, amongst which may be mentioned, the drainage of Royapettah Hospital, the laying of house drain connections in Tondiarpet and the construction of a number of Public Flush-out latrines for the Corporation, and latrines for factories and offices. At the same time designs have been prepared for the drainage of the new Municipal Buildings and for the drainage of the new Hospital belonging to United Free Church Mission, Tondiarpet

Typical designs have been prepared.

174. In the execution of this work typical designs have been prepared for house drainage, house connections, latrines, separation of storm water and silt and details of First-class House Drainage. It was desirable that a certain amount of this work should be done by the Special Works Department in order that it might suit the Drainage Scheme which has been designed for the City of Madras. But now the work is becoming very detailed, is likely to increase largely and it is scattered over the whole Municipal area. In consequence a temporary department, such as the Special Works Department, working with the minimum staff required for construction is not in a position to supervise the work properly. The Special Works Department has one man only for the whole city, whereas a man is required in every division to supervise house drainage —such a man could supervise buildings as well. In order to do this work at all there is at the present time a working arrangement with the Health Officer by which the Sanitary Inspectors receive instructions from the Drainage Superintendent, and after the execution of the work, it is passed by the Drainage Superintendent.

When any second-class drainage work has to be done, a form of notice is filled in by the Drainage Superintendent and forwarded to the Health Officer for signature. The Health Officer's Sanitary Inspector reports as soon as the work has been completed by the owner, or if the owner has not executed the work within the time specified in the notice, then the Health Officer informs the Works Department, whose Overseer carries out the work under the instructions of the Drainage Superintendent. Thus the Works Department are already executing some work under the supervision of the Special Works Department.

Special Works Department should be relieved of detailed House Drainage Work.

175. Now that type designs for house drainage, latrines, etc., have been settled, and byelaws have been framed to deal with them, the time has arrived when, in the writer's opinion, the Special Works Department should be relieved from all the details connected with the house drainage. It is recommended that the Drainage Superintendent be made a permanent officer in charge of a house drainage section under the Corporation Engineer. A convenient time to effect this change would be at the end of 1913 when the temporary agreement of the present Drainage Superintendent (Mr. Cartledge) terminates.

Procedure that might be adopted.

176. If this proposal be adopted, then the procedure with reference to the drainage of buildings, etc., might be somewhat as follows :—

All plans for new buildings would be submitted to the Drainage Superintendent through the City Engineer for scrutiny as to the proposed sanitary work.

The building plans should not be passed until all drainage and sanitary arrangements are satisfactorily shown, as specified in the byelaws, and the form of application filled up to the satisfaction of the Drainage Superintendent, who in case of doubt would consult the Engineer.

Previous to new houses being occupied, a certificate should be given by the City Engineer stating that all drainage and sanitary work is satisfactorily completed.

Permission to occupy newly-built houses should not be given unless the City Engineer's Drainage certificate is produced. The information for the City Engineer's certificate to be supplied by the Drainage Superintendent.

After the Engineer has given his certificate that the sanitary works are satisfactory and in accordance with the byelaws, then, before the house is allowed to be inhabited, a certificate would have to be obtained from the Health Officer that he was satisfied that the house was suitable for habitation in every respect, *e.g.*, that the lighting, ventilation, size of rooms, yard space and other sanitary requirements were properly complied with. In the case of existing buildings where the drainage has to be newly constructed, altered, or added to, the same procedure should be followed.

Work from Health Department.

177. Where improvements in sanitary work are required by the Health Officer, a detailed report should be made of the existing defects and submitted to the Drainage Superintendent for the specification of work required to be written on the notice to be served, the notices to be initialled or signed by the Drainage Superintendent and then submitted to the Health Officer for final signature.

The work would then be carried out under the Drainage Superintendent and the Health Officer notified as soon as it was completed. In cases of non-compliance with the terms of the notices served by the Health Officer, the work would be done by the Corporation under the supervision of the Drainage Superintendent and its cost recovered from the owner of the property benefitted.

Combined Drainage.

178 Where connections are to be put in from a combined drain, *i.e.*, where two or more houses are connected to one main drain—all the house drains to be connected should be made to comply with the byelaws previous to the connection being provided. This could be done by the Health Officer serving notice on the parties concerned.

At the present time, this is not enforced and a great deal of difficulty has been encountered in one or two cases in getting all the owners to comply with the requirements before connections were made. Should a tax be imposed, as suggested by the writer (*see* paragraph 214), on owners of undrained property in districts where Municipal drains are laid, it is highly desirable that, as soon as one owner wishes to connect to a combined drain, notice should be served on all the owners of premises draining to the combined drain to carry out the necessary work in compliance with the byelaws so as to enable a connection to be made to the Municipal drain.

Staff required.

179. For a time, the work [illegible] any person except the Corporation might be supervised by the Sanitary Ins[illegible]s working under the Drainage Sup[illegible]tendent with the Health Officer's pe[illegible]n. The execution of any sanitary [illegible]k by the Corporation might be carried [illegible]y the Works Department Overseers; also under the supervision of the Drai[illegible]e Superintendent. This is the way in which house drainage work—other than connections to sewers—is being supervised and carried out under the existing temporary arrangements between the Health Officer and Special Engineer.

After this arrangement has been working for some time, it will be possible to decide what alterations are required. It would be useless to attempt to forecast them at the present time.

CHAPTER X.

SEWER PIPES, MANHOLES, LAMPHOLES, FLUSHING CHAMBERS, VENTILATORS.

Sewer Pipes.—180. Stoneware pipe sewers. 181. Laying pipe sewers. 182. Timbering. 183. Road restoration. 184. Jointing stoneware pipes. 185. Hassall's joints. 186. Length of sewers. 187. Breakages of pipes in delivery.

Manholes.—188. Manholes (Drawings Nos. 85 and 86). 189. Type of manhole depends upon conditions. 190. Description of mortar to be used in manholes.

Lampholes.—191. Where used. 192. Typical design.

Sewer Flushing.—193. Heads of Sewers. 194. Flushing by subsoil water. 195. Flushing by waste water from public taps (Drawing No. 86-B). 196. Special automatic flushing. 197 Capacity of flushing tanks. 198. Manhole covers (Drawings Nos. 83 and 84).

Ventilators.—199. Different systems. 200. Surface inlets and tall columns adopted for Madras. 201. Considerations which determi[ne] positions of surface inlets and of columns. 202. Mica flap inlets will be used where n[ecessa]ry. 203. Ventilating columns (Drawing No. 8[6] 204. Patent methods of sewer v[entila]tion used only for exceptional conditions. 20[5] lation through house drains.

Sewer Pipes.

Stoneware pipe sewers.

180. Sewers from 4 inches to 21 inches in diameter will, under ordinary conditions, be constructed of English salt-glazed vitrified stoneware pipes supplied according to the writer's specification which has proved perfectly satisfactory as regards the pipes used in Tondiarpet. The pipes will be tested at the manufacturer's works for impermeability, strength, shape and form. Every pipe will be tested for shape and sounded, but only a proportion will be subjected to the internal pressure and impermeability tests.

In the ordinary way, the stoneware pipes will be laid directly upon the ground forming the bottom of the trench, but where the ground is bad, or the depth exceeds the limits fixed by the Special Engineer, the pipes will be bedded on and surrounded by concrete.

In the case of the writer's Tondiarpet proposals, objections were taken to laying pipes below sub-soil water level on the ground—

(1) that sewage would get out of the sewers and pollute the sub-soil water, and

(2) that water would get into the sewers and thus largely increase the quantity of pumping.

These are two very serious objections, but fortunately if reasonable care be exercised the sewers may be made watertight. Brick sewers will be made watertight by means of a coating of cement plaster inside and a coating of combination mortar plaster outside. To ensure that there shall be no leakage with stoneware pipe sewers, Hassall's double lined safety joints will be employed

where much water is encountered. Where very large quantities of water are encountered and the sewers are laid at a considerable depth below the surface of the sub-soil water, neither brick sewers nor stoneware pipes will be used. Cast-iron pipes with socket and spigot joints, caulked with lead wool will be employed. Finally, to prove that the sewers are watertight, they will be tested under water pressure before and after the earth has been filled in over them. Should any leakage be discovered by these tests, it will have to be remedied before the sewer is passed. In Appendix I is a table showing the lengths of pipes of different sizes to be laid below average subsoil water level in each drainage division.

It is intended, as far as possible, to let out on contract both the pipe laying and brick sewer construction. A departmental gang will be formed, however, to carry out especially difficult work and to take over pipe laying and other work, should any contractor prove to be unduly dilatory in his work.

Laying pipe sewers.

181. It will be insisted that all pipes shall be laid true to lines and levels and carefully bedded along the whole length of the bottom of the trench. Boning rods and sight rails will be used in laying every pipe, the foot of the boning rod being so finished that, when inserted into the mouth of the pipe that is being laid, it shall rest properly on the true invert of the pipe when the boning rod is truly vertical. If any pipe or pipes on inspection are found to diverge from the true lines and levels, the contractor will be required to take them up and relay them at his own cost.

Timbering.

182. Owing to the considerable depth at which it has been decided to lay a number of sewers, the question of timbering is one of great importance.

In Tondiarpet it has been impossible to secure good timbering. In fact, the only satisfactory timbering has been that which has been executed departmentally for trial holes. It is, therefore, proposed to issue detailed timbering drawings with the contracts and to insist that a certain quantity of timber shall be delivered at the work spot before excavation is started. This will have the further advantage of tending to prevent inexperienced contractors from tendering at rates too low to make a profit, for they will at any rate know the cost of timber that they will have to provide.

Road restoration.

183. In the sewer-laying contracts, it will be specified that the contractor must restore the condition in which they were before the surfaces were disturbed, the metal being carefully replaced on the surface; and that the contractor will have to maintain them in a condition safe to the traffic until they can be handed over for reform.

It is proposed that the final restoration of road surfaces disturbed by the trenches excavated for sewer-laying shall be carried out by the Works Department. In Tondiarpet, the reform of road surfaces had been postponed until after the laying of the sewers. In consequence many of the road surfaces were in a bad condition when the sewer trenches were first excavated, and it was convenient for the Engineer to restore the whole width of the road at one time. This has involved for the trench itself a cost considerably in excess of that required for restoring the surface to the condition in which it was when the sewer-laying operations were commenced.

The arrangement come to in Tondiarpet was that the drainage works

should be debited with 30 per cent. of the cost of the complete reform of the width disturbed by the sewer laying operations. Under this arrangement, the payments up-to-date have been Rs. 943 for the restoration of 5,895 lineal feet of sewer trenches. This works out at about As. 1½ to As. 3 per lineal foot including the cost of house connection trenches as well as the sewer trenches themselves The roads to which these figures refer are metalled roads, whereas there are a large number of unmetalled roads which require no restoration beyond that done by the contractor. The cost in Tondiarpet will probably work out on the average at about As. 1½ per lineal foot of sewer trench. Tondiarpet is, however, not typical of the rest of Madras, because it has a larger number of unmetalled roads. After carefully considering the matter, the writer proposed and the President has agreed that the following rates, which have been included in the estimates, should be paid to the Works Department :—

Diameter of Sewer.	Rate.
6 inches	2 annas.
9 „	2½ „
12 inches and 15 inches	3 „
18 „	3½ „
21 „ and 24 inches	4 „
30 „	4½ „
3 feet and above	5 „

These rates include the cost of restoring both the sewers themselves and the trenches excavated for house connections to sewers. Each road will be handed over to the Works Department as soon as the sewer laying in that road has been completed and the manholes built, though house connection pipes may not have been laid. The above rates include a small expense that will be incurred maintaining the road surfaces from the time they are handed over until the restoration is put in hand.

Jointing stoneware pipes.

184. The ordinary stoneware pipes will be jointed by carefully wrapping round the spigot a ring of spun yarn dipped in cement grout or tarred gaskin sufficiently thick to fit properly the socket of the adjoining pipe and to give proper alignment, the yarn being carefully driven home and caulked, so as to leave the required depth. The jointing material will consist of a mixture of 1 part cement and 2 parts sand which will be filled into the space in the sockets and will be neatly levelled off on the outside of the pipes and finished at an angle of 45 degrees outside the socket of the pipes. Great care will be taken that none of the jointing material shall be left inside the pipes. To this end, all pipes will be carefully brushed out before being laid, and a sufficient shield will be placed within the mouths of the pipes to prevent stones, rubbish, etc., getting in. Furthermore, a tightly fitting bag of shavings or straw, having a rope attached, will be kept inside the pipes and will be worked forward as the pipe laying proceeds, so as to remove all the obstructions from the interior, and especially to wipe away any cement jointing material which may have penetrated the gaskin.

185. As already stated, Hassall's double lined joints will be used where much water is encountered. In these joints, there are two composition bands cast on the outside of the spigot which engage similar bands cast inside the

socket of the adjoining pipe. Before the spigot is inserted into the socket, these bands are smeared with plastic cement, to assist in making the annular space watertight. To prove this watertightness the annular space will then be filled with water. If the water surface remains stationary, then it is proved doubly watertight —both inwards into the pipes and outwards through the socket—and the joint is run with a grout of neat cement and water until the annular groove is filled up. Should the surface of the water sink, then the joint will have to be taken apart and re-made before the cement grout is poured in.

186. The lengths of the larger and more important sewers have been determined by actual measurements on the ground. No useful purpose would have been served at the present stage by measuring all the street sewers, aggregating 84 miles in length. The lengths of these sewers were determined by measuring on maps of Madras to the largest scale obtainable. From experience of scaling many miles of sewers and water mains for the water supply and for the Tondiarpet Drainage, and subsequently measuring the lengths on the ground, it has been found that the lengths, as obtained from the Survey Plans, should be increased by an amount varying from 1 to 4 per cent. An allowance of $2\frac{1}{2}$ per would meet most cases, and this allowance has been made in the present me

187. The cost of stoneware pipes of all kinds has increased considerably the preparation of the estimates for the drainage of Tondiarpet. Thus stoneware pipes, both for plain and Hassall's joints, have increased by some 25 per cent. in cost. This is, to some extent, due to the considerable number of breakages in course of delivery to the stores in Madras. The percentages of breakages, according to different sizes, are given in the following table :—

Description.	Ordinary S. W. Pipes.			Hassall's Patent Pipes.			Number of bands damaged	Percentage of damaged bands.
	No. delivered	No. broken.	Percentage of breakages.	No. delivered	No. broken.	Percentage of breakages.		
4″ Pipes	21,692	922	4·25	...	...	...	...	...
6″ „	38,885	5,866	15·09	...	...	...	...	...
9″ „	20,757	3,237	15·59	9,431	355	3·76	494	5·24
12″ „	1,056	273	25·85	3,509	141	4·02	232	6·61
15″ „	...	...	...	1,882	58	3·08	151	8·02
18″ „	265	40	15·09	503	17	3·38	105	20·87
4″ × 4″ Junc.	14,589	680	4·66	...	...	...	...	...
9″ × 4″ „	5,720	899	15·72	2,405	296	12·31	201	8·36
12″ × 4″ „	84	14	16·66	923	157	17·01	68	7·37
15″ × 4″ „	...	...	...	565	168	29·73	19	3·36
18″ × 4″ „	159	70	44·02	180	59	32·77	39	21·67

In addition to breakage in delivery to stores, there is also a loss between ores and final laying. This amounts to about 1 per cent. for ordinary straight pes, and 2 per cent. for junctions.

No. 15728

Manholes.

Manholes (Drawings Nos. 85 and 86).

188. All street sewers will be furnished with manholes spaced not more than feet apart on straight lengths. Manholes will also be placed at all angles he pipe lines.

Typical manholes for Madras are shown on Drawings Nos. 85 and 86. wing No. 85 shows rectangular manholes and Drawing No. 86 shows ılar manholes. The types on both drawings are designs prepared for actual holes at definite points in the drainage system.

A study of the drawings will give more information than can be con- ed by any description. The drawings show typical shallow manholes, drop holes for a connection of a rider sewer with a main sewer, and junction manholes between two sewers, at approximately the same level, etc.

Except where rectangular manholes are called for by the peculiar circumstances of the case, circular manholes will be adopted throughout the system for the reason that they are cheaper and stron in a circular manhole 9 inches of brickwork is sufficiently strong to resist ushing force that is likely to be applied by earth pressure, but this thick s not sufficient to ensure water-tightness under considerable pressure, and therefore in de oles the lower part of the walls will be thickened to 14 inches. The inverts of all main s will be constructed of concrete shaped to form smooth U-shaped channels and plastered with cement mortar, so that if the pipes ever run full, the sewage will remain confined to its proper channel and will not spread out in the manhole and deposit filth on the benchings. The benching themselves will be sloped, so that should the sewage overflow them at any time, it will quickly run off as soon the sewer is dewatered as the flow decreases. In the junction manholes, the pipes will be so arranged that the axis of the incoming sewer is at least as high as the axis of the main sewer which it joins. This is necessary in order to prevent backing up of sewage along a small branch sewer where it joins a larger main sewer, as often happens in the old Madras sewers, in which the rule was to lay the inverts instead of the axis at the same level.

It will be noticed that all the down pipes are shown 4 or 6 inches in diameter. When they have to take the sewage from a larger pipe, a diminishing pipe or a tumbling bay with 4 inches or 6 inches junction as required will be inserted for a 6-inch pipe is amply large enough for the down pipe in every case that has so far been designed.

At the top of the down pipe will be a special "tumbling bay" junction with its invert smoothly curved along the line of flow of the sewage as it comes along the branch pipe and turns down the vertical pipe. The object of the smooth curve is to assist the easy flow down the vertical pipe and to prevent the liquid shooting across it. The end of the junction will be closed with a stopper which can be removed for inspection and cleaning purposes.

Type of manhole depends upon conditions.

189. The type of manhole to be adopted in any case will depend upon the conditions. The rectangular manhole is more suitable for shallow sewers and also in those cases where a number of sewers meet at a manhole. On the other hand, the circular manhole is both stronger and more economical, and will, in a general way, be adopted for all sewers of 6 feet or more in depth to invert. In circular manholes, the sides will be brought up vertically to within

6 feet 6 inches of ground surface. From that point one line will be continu vertically, so as to provide an easy means of getting up and down the manho the remainder will be tapered inwards, so as to finish off at the under s. manhole cover with a clear opening of 18 inches. All brickwork above sub-s water level will be constructed in "combination" mortar. Below water le cement mortar will be used.

Description of mortar to be used in manholes.

190. All manholes will be plastered internally with ¾-inch cement pla and externally with combination mortar $\frac{5}{8}$-inch thick. This plastering serves purposes: (1) to make the manholes watertight; (2) to preserve the brick-wo

The latter is a necessity in Madras where a good class of engineeri brick has not yet been manufactured.

Lampholes.

(Drawing No. 86-A).

Where used.

191. For the sake of economy, and also to avoid filling the road with masonry chambers, lampholes will be used to replace manholes in streets where bends and angles are very numerous. Where a bend is situated between two manholes not more than 300 feet apart and is required solely for a change of direction, it may properly be replaced with a lamphole. Lampholes will also be used at the heads of short rider sewers. These sewers will be laid principally where the main sewers are deep. They are comparatively short, and can be laid at steep gradients, and can be cleaned from the manhole where they connect with the main sewer. Lampholes at the head of rider sewers will furnish ample means for such flushing as may be necessary and will also provide an eye through which a lamp may be lowered for inspecting the sewer. In any case, the rider sewer will be so shallow that a manhole at its head would not be sufficiently deep for a man to work in.

Typical design.

192. A typical design for a lamphole is shown on Drawing No. 86-A. This shows a lamphole at an angle of a sewer. The sewer bend is made at the base of the lamphole in a very small chamber from which a vertical stoneware pipe 9 inches or 12 inches in diameter extends nearly to the road surface The upper end of the pipes is surrounded by a small brick chamber surmounted by a closed or open cast-iron cover similar to a manhole cover but smaller, an open cover being used where the lamphole is required to act as an air inlet and a closed cover where it is not so required. A detail of the lamphole cover is shown on Drawing No. 84.

Sewer Flushing.

Heads of sewers.

193. The manholes at the heads of all sewers will be so constructed as to be suitable for flushing purposes. A simple form of portable flushing disc will be used to close the manhole outlet which will then be filled with water either from a neighbouring hydrant or by means of a water-cart. When the manhole is charged, the disc will be removed and the rush of water will flush the sewer. The only objection to this system is that any house drains connecting directly into sewer head manholes used for flushing would be temporarily surcharged, the air in the connections would be then compressed and driven through inter cepting traps. To avoid this trouble, no house drains will be connected to the sewer head manholes, and except, as a temporary expedient, no manholes other than head manholes will be used for flushing by this system.

194. An interesting suggestion that has been made is to use sub-soil water for flushing, by constructing a small well by the side of each flushing manhole, where the conditions are suitable, and pumping the water into the manhole by means of a small portable hand pump. The great point about the proposal is that the public water-supply, which is certainly not excessive, will not be drawn upon for flushing, as it would if the pipe water were used. The value of this proposal will be carefully considered, and some trials will be made with such system should it appear feasible. **Flushing by sub-soil water.**

195. Where practicable, the waste water from public taps will be utilised for sewer flushing and special automatic flushing chambers, such as that shown on Drawing No. 86-B will be used for this purpose. The design shown is intended to suit a shallow sewer head, but with slight modification can be applied to flush sewers of any depth, and the arrangement can be fed from any public tap, cattle trough or place where water is at present spilt or wasted. Where the sewer head is very shallow, the platform round the tap will be raised a foot above road level. All waste water will drain to the flushing tank through a silt catcher to remove the sand and silt brought to the washing platform by the feet of persons using it. Where the head over a sewer at 3 feet 6 inches or more in depth, the tops of the flushing tanks will be furnished off to the level of the road surface and the platforms will be at normal level. For deeper sewers, the tanks will be entirely underground. **Flushing by waste water from public taps (Drawing No. 86-B).**

196. In most of the drainage areas, there are some sewers which are designed to be provided with flushing chambers; for instance, where the district is expected to grow rapidly and where the sewers have now to be laid large enough for the future population. In such cases the flow at the time of laying the sewers may not be sufficient to make them perfectly self-cleansing and flushing is necessary. Another example is afforded by those main sewers which will not be completed at the present time, but will be laid as far as required to await extension in the future. These main sewers will not receive the full volume of sewage for some years after they are laid and will require sytematic flushing to keep them clean. **Automatic flushing.**

197. The useful effect of a large flush operating at considerable intervals is much greater than the same volume of liquid used in smaller flushes discharged at correspondingly shorter intervals. Consequently, it is proposed to use in Madras, flush tanks of large size which will not be less than the following:— **Capacity of flushing tanks.**

6-inch sewers	...	...	250 to 400 gallons.
9 ,, ,,	...	...	450 to 550 ,,
12 ,, ,,	...	...	900 gallons.
15 ,, ,,	...	...	1,500 ,,

These will be arranged in most cases to work about once a day, as this interval has, as a rule, been found sufficient. Wherever waste water from taps, etc., is inadequate, a suitable tap properly isolated from sewer gas will be provided to supplement the waste supply.

198. Typical manhole covers are shown on Drawings Nos. 83 and 84. These are of two patterns—the closed pattern and the open pattern—so constructed that they are interchangable. Should any nuisance arise from an open manhole cover, it can quickly be replaced by a closed cover. These covers will be made in Madras, as it has been found that European firms cannot compete in price with local manufacturers. A large number of covers of the type shown have been used in various parts of Madras and have proved perfectly satisfactory. **Manhole Covers (Drawings Nos. 83 and 84).**

Drawing No. 83 shows a light air-tight square cover suitable for hou drains. A number of these have been used satisfactorily on the drainage Kalyani Hospital, Ophthalmic Hospital, Royapettah Hospital, and priva drainage works.

Ventilators.

Different systems.

199. The ventilation of sewers has been a subject of controversy and expe ment for many years past in England. Some few believe in no ventilation at a advocating that all sewers be sealed up as much as possible. A second opinic is held by others, who believe in using shafts as vents, but consider it useless attempt ventilation.

A great body of opinion, however, has come to regard the system of t columns and a right number of open street gratings as an effective and practical method of ventilating sewers.

Surface inlets and tall columns adopted for Madras.

200. In Madras, the conditions of climate are favourable to sewer ventila- tion on the column and grating system, because the sun is powerful and the temperature is equable, varying slowly; the normal directions of the wind are well defined, the city is flat, and the sewer air of one district, liberated from tall columns, will not sweep over and cause a nuisance to higher districts. In hilly towns this is at times a considerable difficulty.

Open grated covers will be put on the manholes where required, to act as air inlets to the sewers; the outlets will be tall columns, normally 6 inches in diameter and usually from 20 to 30 feet high.

Considera- tions which determine positions of surface in- lets and of columns.

201. It has been found that in ventilating sewers nothing can be done by exact rule. The position of each column and every open grated cover must be considered and determined intelligently on its own merits. Proximity and height of houses, main directions of wind, the amounts of sunshine and shadow on each column, the levels of the ground, the paths likely to be taken by the sewer air, issuing from columns, all these must be thought of before fixing a single column or deciding the position of one tentative inlet. The inlets at road level should be put as far from houses as possible, so that they will do no harm if at times they act as outlets through adverse or unconsidered conditions. If found to be acting as an outlet, the grated cover can be replaced at once by a closed cover, and a new position tried.

Open grated covers will not in Madras be placed where the roadway is likely to be flooded by rainwater during the monsoon, for such water would rush into the sewer; but where an inlet is needed in a street liable to flooding, a pipe will be brought to the closed manhole from a raised inlet fixed at the roadside.

The action of ventilating columns generally overcomes or at least counterbalances any adverse conditions produced by light winds: and when a high wind temporarily upsets some part of the normal ventilation, it must not be forgotten that there is also enormous dilution and diffusion of any gas escaping at street level.

Mica flap inlets will be used where necessary.

202. In special cases mica flaps will be used to prevent occasional efflux of sewer air from inlets; but mica flaps get out of order rather easily and require frequent inspection. If in the least "get-at-able" they are certain to be damaged by children and mischievous persons. They need careful placing.

Ventilating columns (Drawing No. 86-C).

203. Ventilating columns, if high enough, require less care in placing than do inlets. The numbers of inlets and outlets required by a sewer system vary according to circumstances. Badly laid sewers, producing much gas, require more columns than do first-class self-cleansing sewers. Cold climates reduce the amount of ventilation required, hot climates, however, are not believed to increase the number of columns needed, because the sun in hot countries can be depended on to heat the columns regularly and cause more rapid movement of the sewer air. Wind blowing normally across the top of a tube causes an up-draught inside it ; further, if a ventilation tube is heated by the sun, the air inside it becomes bulk for bulk lighter than that outside : the lighter air is then forced up the tube by the cooler and heavier air entering beneath from the sewer. It is largely owing to these two causes, wind and temperature differences, that sewer ventilating columns do their work. In Madras, there is a hot sun by day, and more or less breeze stirring as a rule and the column system may be expected to give at least ordinary satisfaction.

Drawing No. 86-C shows typical ventilating shafts. The ordinary shaft will be of steel 6 inches in diameter and 25 feet high. It will be provided with a rust pocket. Large steel shafts 12 inches to 24 inches in diameter of heights up to 40 feet or more will be used where required. In cases where steel shafts would be unsightly, brick shafts will be employed. A design for such a shaft is shown on Drawing No. 86-C.

Patent methods of sewer ventilation used only for exceptional conditions.

204. Few, if any, patent methods of sewer ventilation have been a success on a large scale, and all are costly. Some of these systems have been used on a small scale for attempting to deal with especially foul and defective sewerage work, and there are sometimes cases where exceptional expense may be incurred by wealthy Corporations, in order to use special means for the ventilation of sewers ; as in some very important street where high buildings make the column system difficult to use, or in a case like that of the Houses of Parliament, where a specially costly system of drainage and ventilation was permissible.

Of the patent methods of sewer ventilation, the lamp column is, perhaps, most pushed at the present time. While single lamps are useful at particular points, where, for some special reason, it is undesirable to fix ordinary columns, yet they cannot be recommended for general use throughout the city.

Ventilation through house drains.

205. A Committee was recently appointed by the English Local Government Board to consider the advisability of fixing intercepting traps on first-class drainage connections to sewers.

In their report the Committee state clearly that the intercepting trap may be omitted. It was found that sewer gas was certainly no more foul than that produced in the house drains. In the Bye-law No. 21 (*see* Chapter XXI), it is proposed that a disconnecting trap is to be used only where required by the Engineer. In first-class house drainage, the trap will, as a rule, be omitted. All the soil pipes of premises drained on first-class lines will thus become ventilators for the Municipal sewers and the necessity of special means—open gratings, columns and the like—will be diminished. Intercepting traps will, however, continue to be necessary with second-class house drainage, and in Madras it will be many years before the house drains will provide all the ventilation required by the Municipal sewers.

CHAPTER XI.

HOUSE DRAINAGE AND HOUSE CONNECTIONS.

206. Division of subject.

House drainage.—207. Classes of house drainage. 208. Advantage of first-class drainage. 209. First-class drainage. 210. First-class drainage works already in hand. 211. Second-class drainage. 212. Separation of rain-water from sullage in second-class house drainage. 213. Grating at street end of house drain. 214. Installation of flush-out latrines and water-closets in houses with first-class drainage with second-class drainage. 215. Power to enforce house connections. 216. Power to enforce water-closets. 217. Cost of alteration of house drainage. 218. Drainage of Paracherries. 219. Exclusion of silt and storm-water from side drain connections. 220. Madras storm-water separator. 221. Elimination of silt and rubbish.

House Connections.—222. House connection for houses with first-class type of drainage. 223. House connection for houses with second-class type of drainage. 224 Vertical shafts. 225. Exclusion of silt. 226. Cleaning arm. 227. Provision for testing house connection. 228. Number of house connections.

206. In dealing with house drainage and its connection to sewers, it is convenient to divide the subject into two sections— **Division of subject.**

(1) House drainage by which the domestic sewage is collected and delivered to the side of the street.

(2) House connections by which the sewage is conveyed from the side of the street to the Municipal drain. In this section these two divisions will be considered separately.

House Drainage.

207. House drainage in Madras may be divided into three classes— **Classes of house drainage.**

(1) *First-class* on the water carriage system for those houses and buildings that are furnished with water-closets, baths, lavatories and sinks drained on European lines.

(2) *Second-class* drainage, retaining the open house drains at present used. This system would be used for the ordinary small houses of Madras in which it would be most unwise to introduce underground drainage into the houses.

(3) There are also paracherries and collections of huts where each habitation cannot be provided with a separate connection to sewers. These would be provided with suitable latrines.

208. The second and third of these three classes should be regarded as temporary and everything should be done to encourage first-class drainage which has the following advantages:— **Advantage of first-class drainage.**

(1) Excreta and urine are rapidly removed without causing any nuisance.

(2) Filthy hand scavenging which now employs hundreds of men, women and children is abolished.

(3) The cost and nuisance of conservancy of nightsoil and the cost of nightsoil depôts and trenching grounds are done away with.

First-class drainage can, however, be introduced only gradually because of the expense, and the necessity of first educating the mass of the inhabitants to work the system properly for with improper use the system would give great trouble. There is no doubt, however, that as this system is installed by ho[illegible] hotels, clubs and more gradually by private persons, the gr[illegible]nliness will be much appreciated and, as in Bombay, a general demand will arise in the community for the first-class type of drainage.

First-class drainage

209. In a first-class house drainage system, the arrangements will be practically the same as are used in Europe and America. No attempt will be made here to describe this system as it would involve more space than is available here. The byelaws proposed in Chapter XXI set out in detail the requirements of a first-class house drainage system. These, together with the detailed drawings shown on Plates XXV—XXXII, will give sufficient information to those who wish to construct this work. One point, however, should be referred to and that is the disconnecting trap. The writer agrees with the opinion recently expressed by a Committee of the English Local Government Board that intercepting traps are not necessary and he would advise that for first-class drainage they should not be allowed except under special circumstances for the following reasons :—

(1) Risk of stoppage of the drains is diminished.

(2) The ventilation of the sewers is much assisted.

First-class drainage works already in hand.

210. The writer's department has already prepared designs and has supervised the carrying out of first-class drainage for the Royapettah Hospital, and has prepared designs for the new Municipal buildings. Designs have also been prepared in his department for the Free Church Mission Hospital in Tondiarpet. Other buildings that have, within the last few years, been provided with first-class drainage are the Maternity Hospital, Ophthalmic Hospital and D'Angelis Hotel, while Government is understood to contemplate installing the system in the General Hospital and Lunatic Asylum. Sanitary Engineering firms have prepared plans for the drainage on first-class lines of the Bank of Madras and the National Bank of India. Further, the writer has had enquiries from a number of private persons. There is thus already a demand for first-class drainage and as it is very important that such a drainage should be well done, if it is done at all. Byelaws, governing the principles of its construction, the materials and workmanship to be used therein, have been prepared, more or less, on the lines of those adopted by the London County Council. These byelaws, with any modifications that may be required, should be adopted with the least possible delay, for if a system of byelaws are in force before the drainage works are commenced, the Corporation will have taken every reasonable precaution to ensure that no bad work shall be constructed in Madras.

Second-class drainage.

211. For many years to come first-class house drainage will be impracticable in the bulk of the houses of Madras for the following reasons :—

(1) The expense of installing underground drainage throughout the poorer class houses would be prohibitive.

(2) Owing to the way in which the majority of houses are built together, drainage to the back is impracticable. A covered pipe would therefore have to be laid from the front right through the house. This would be difficult and dangerous because of the likelihood of damage to the walls by digging trenches close to and, in many cases, under the house walls.

(3) Flushing would be absolutely necessary and would entail water service and flushing cisterns.

(4) It is likely that, if underground drainage were introduced into poorer houses wholesale, it would be a failure.

Every sullage water entrance to an underground pipe drain must be provided with a siphon which, in the ordinary Indian house, must be protected by a silt-catcher and grating. These gratings and silt-catchers would have to be fixed inside the house and would require attention which, at present, they would not receive. The result would be the same failure that took place in Bombay where a great deal of underground house drainage had to be taken up and open channels substituted. For these reasons, the conclusion has been reluctantly reached that underground pipe house drains would at present be quite impracticable in the majority of Madras houses In the circumstances the best plan is to utilize the present open drains which should be suitably modified so as to separate the storm-water from the sullage. The method of doing this is shown on Drawing No. 82 and Plate X where the rain-water drain is coloured green and a separate sewage drain is shown in yellow.

Separation of rain-water from sullage in second-class house drainage.

212. The separation of rain-water from sewage in a second-class house drainage system will be effected by small brick or concrete curbs as shown in red on Plate X. These curbs divide the court-yards into washing places and rain-water areas. Rain falling on the roofs will pour off the eaves, and falling on to the court-yard will be caused to flow at once into a "U" shaped storm-water drain by which it will be conveyed to the street side drain. The soiled water from washing places and that from household utensils will be directed by the curbs into the sewage drain coloured yellow on the drawings. A good deal of washing is done on the verandahs surrounding the court-yard ; a small open channel will therefore be made round the margin of each court-yard and will be protected from rain-water by the usual curb. This channel from the verandah, it will be seen, empties into the sewage drain. By this means a practical working separation of rain-water and sewage will be effected. The method here proposed for the separation of rain-water from sullage has been carried out in the case of a number of houses that have been drained under the supervision of the Special Works Department. No difficulty should be experienced in getting the work done when the new bye-laws have been passed. The extra expense in the case of new buildings would be insignificant. This separation has not been carried out

in the past, and has resulted in the surcharging of sewers in the lower sections of each district by the rain-water which freely enters the system at higher points, whenever there is heavy rain. To prevent this flooding and to keep the system in proper working order it is absolutely necessary to separate the rain-water from the sullage.

In some cases, the rain-water and sewage drains will be closed for short distances. For instance, the sewage drain will be closed where it is found that rain-water entering it and the rain-water drain will be closed wherever there is danger of sewage flowing into it. Governing these two principles is that of free access and no drain or part of a drain should be allowed to be constructed that cannot be quickly examined and easily cleaned, when necessary. By throwing a bucket full of water down the sewage drain once or twice a day, it should be thoroughly cleaned out and there should be no smell or unhealthiness, though it would be an advantage to place a small flushing tank at the head of the open drain.

Grating at street end of house drain.

213. Near the street end of the sewage drain in a second-class house drainage system will be placed a sloping iron grating as shown on Plate X. This grating is of special design to allow the passage of silt but to catch all leaves, sticks, etc., without arresting the flow of sewage or destroying its silt transporting powers. Some such special arrangement is badly needed for the gratings that were formerly installed are continually causing the house drains to block up, forming a length of stagnant sewage at the low end of the house drains.

Installation of flush-out latrines and water-closets in houses with second-class drainage.

214. Although underground pipe drains from end to end of the closely built-up houses are not recommended for the reasons given, yet it should be insisted that the present dry latrines should be replaced by flush-out latrines situated next to the road, so that a short length of cast-iron pipe can be used to take the sewage direct to the sewer connection without passing through the silt-catcher or sullage water siphon. Drawing No. 82 and Plate X show how a cheap flush-out latrine can be installed. If this type of flush-out latrine is not installed in any house, within a period limited by the Corporation President, a tax should be levied on the house-owner to cover the cost of the removal of night-soil and its disposal, for the Corporation, having at a considerable expense installed what in their opinion is the best means of disposing of night-soil, cannot continue to maintain another expensive system as well.

It may be well here to state briefly the powers under which the Corporation would be able to enforce the use of the water-carriage system.

Power to enforce house connections.

215. In the clauses of the Act and Byelaws given in Chapters XX and XXI, it is proposed to give powers to the Corporation to enforce the drainage of undrained premises within a 150 feet of a Municipal drain.

Under Clause 13 proposed for the new Act, the President is empowered to enforce the drainage of undrained premises within a 150 feet of a Municipal drain. This power is already possessed by the Corporation under Section 218 (1) of the existing Madras City Municipal Act of 1904

Power to enforce water-closets.

216. Under proposed Clause 32, the President, with the previous approval of the Standing Committee, is empowered to require the owners of premises to instal water-closet accommodation, or to substitute water-closet accommodation for privy accommodation. If these requirements were not complied with, the parties would be prosecuted in the Police Court under the section of the Municipal Act dealing with the fines which may be imposed for contravention of various clauses, paragraphs and sub-paragraphs. For continuing an offence, the parties could again be prosecuted under the section dealing with continuing offence, and after conviction would be liable to a daily fine.

The Municipal Commissioner for the City of Bombay states that in Bombay no difficulty has been experienced in compelling the fulfilment of Municipal requirements in the case of either connections to sewers or installation of water-closets. His letter dealing with this matter is printed in Appendix No. VI, page 269

Cost of alteration of house drainage.

217. The Health Officer has been requested not to pass any new house as fit for habitation until the drainage has been approved by the Engineer. To obtain this approval, the house drains will have to be in accordance with the requirements of the byelaws, and proper provision will have to be made for the separation of rain-water from sewage. The Corporation has also decided that the whole cost of the connection will have to be borne by the owner. In the case of existing houses, however, it is not so simple a matter.

Clause 218 of the existing Municipal Act gives power to the President to enforce construction of house drains, and Clause 227 gives the control of all house drains to the Corporation and states that they shall be altered or [illegible] and kept in proper order at the expense and charge of the owner of the building. Whether these clauses give the President power to make the owner alter the drains at his own cost, so as to make them suitable to be connected to the new underground drainage system is doubtful

The Standing Committee on 12th January, 1912, passed a Resolution (No. 27) that the owner has to pay for any "alterations required in the drainage of his house and also for connecting the drain to the siphon trap by a cast-iron pipe, or such other means as may be ordered by the President." Whether the Corporation have power to enforce this resolution appears to be doubtful. It would appear that there is at present a "place of outfall" within the meaning of Clause 218 of the Act into which house drains already discharge. In these circumstances, it might be held that, if the Corporation insist upon a connection to a different place of outfall and in a different manner, the expense of carrying out the necessary work should be borne by the Corporation. This is a very important point for it refers to the whole of the existing houses in Madras.

The cost of alteration of drainage of each house may be taken as not less than Rs. 50 and the suitable connection of the house drainage to the siphon trap would cost about Rs. 8. If the total number of existing houses to be connected to the system be taken as 30,000, then the total cost of the alteration of the house drainage and of the connection of the house drainage to the siphon trap would amount to Rs. 30,000 × 58=Rs. 17,40,000. A very large sum is therefore involved.

Reference may, however, be made to Clause No. 221 of the Act by which it would appear that the President may enforce the construction and maintenance of proper troughs and pipes for connecting and carrying the water from the roof and other parts of any building and for discharging the same into the side drain. In other words, it would appear that the President may insist upon the separation of rainwater from the sullage water. This is the principal point which it is desirable to insist upon in house drainage, and if it is decided that the President has this power, then Rs. 15,00,000 out of the Rs. 17,40,000 will be borne by the owners. If the cost of connecting the house drainage to the siphon trap has to be borne by the Corporation, then the Rs. 2,40,000 must be added to the total of the estimates. If the Corporation have, in addition, to alter the house drainage so as to make it suitable for connecting to the sewerage system, then the total of Rs. 17,40,000 must be added to the estimate.

Drainage of Paracherries

218. For a long time to come, there will exist in Madras, Paracherries and collections of huts where each separate dwelling cannot be provided with a connection to a sewer. In such cases, the most practical method is that adopted by the Madras Corporation in the construction of Model Paracherries to have a sufficient number of suitable latrines for the use of the inhabitants of Paracherries and to provide the houses with a good class of side drain for the removal of sullage water. These side drains should be protected by constructing a low curb on the road side a little higher than the road level. This will prevent stones and sand being washed into them and will obviate a great deal of the labour which is at present expended in clearing road metal out of drains after heavy rains.

Exclusion of silt and storm-water from side drain connections.

219. It is of vital importance that the connections of these side drains to sewers should be made properly and apparata of different descriptions have been designed for Madras. They include—

(1) Ordinary Overflow Weirs.

(2) Leaping Weirs.

(3) Plate Weirs.

In the case of the ordinary *Overflow Weir*, the inlet to the sewer is constructed so that when the flow exceeds the maximum allowable, the excess water passes over a weir provided for the purpose, and flows away to the storm-water drain.

In the *Leaping Weir* method of separation, the liquid normally drops down an opening in the drain into a pipe leading into the sewer. In times of rain when the flow becomes excessive, the rush is sufficient to carry the liquid right across the opening into the rain-water channel.

The *Plate Weir* is an alternative to the Ordinary Weir. In this case, a plate is placed across the channel at such a level that the dry weather flow passes freely underneath it, but in times of rain the level of the liquid is raised until it reaches the plate when a portion of it passes over the top of the plate and is diverted into the rain-water drain.

The Plate Weir has this advantage over an Ordinary Weir that the quantity which flows to the sewer diminishes slightly as soon as the overflow comes into operation, the reason for the reduction in flow is that when the liquid surface touches the plate, the friction between the water and the plate reduces the rate of flow. The action is analogous to that of an ordinary pipe which discharges more when $\frac{9}{10}$th full than when flowing just full.

The most suitable, to the particular case of these three types of storm-water separators, will be used where necessary and possible. If there were an underground system of storm-water sewers no other method would be required.

Madras storm-water separator.

220. Owing to the absence of rain-water drains, there is flooding in hundreds of streets during heavy rainfalls, such as would completely submerge any separators placed on those streets. The types of separators described above would be of little use in these circumstances.

In fact the Ordinary Weir and the Leaping Weir types would form openings down which an immense quantity of silty water would rush into the sewers. The Madras type of separator has been designed to work when totally submerged. It is exceedingly simple and consists merely of a small chamber at the end of the open drain in which floats a ball made of wood, copper, or other suitable material.

Details of suitable separators for various conditions are shown [illegible] Drawings 87 to 92. Plate XI shows one on a side-drain connection. The drain discharges into a silt-pit through which the sullage passes on its way to the separator chamber which is provided with a suitable cover or grid. In the most convenient side of the Separator Chamber is formed the outlet connecting with the pipe which leads to the sewer. This pipe is provided with an Intercepting Trap and, if required, may be fitted with a ventilator and an inspection shaft. A grating is fixed at the inlet end of the silt-pit, and a second grating is provided to protect the regulator. An Overflow Weir is formed on one side of the drain close to the point where it enters the silt-pit. In times of heavy rain, the storm-water is discharged over this weir into an overflow channel when the outlet has been closed or partially closed as described below.

The storm-water separator consists of a ball valve which may be made of wood, copper or other material and is weighted so that it shall be submerged to the required depth. The ball is made of such a size and shape that when in register with the outlet, it wholly or partially closes the same, according to the amount of liquid that is to be allowed to enter the sewer. The floor and walls of the chamber between the silt-pit and the outlet are shaped to serve as a path or guide for the ball valve as it is carried along through the liquid flowing through the chamber. The ball constitutes the means of controlling or regulating the flow through the outlet. The liquid in passing towards the outlet causes the ball to remain in engagement with the curved path formed in the floor of the separator chamber. Starting with the silt-pit emptied and the ball valve at the lowest point of its path, then as the surface of the liquid rises, the ball also rises and partly throttles the outlet, permitting only a definite quantity of liquid to pass through it. When the liquid reaches a pre-determined level,

the ball valve closes the outlet as completely as is allowed. By varying the contour or profile of the ball path, or by varying the size and shape of the ball valve or orifice, or by altering the weight of the ball valve, the flow may be regulated as desired. To assist in retaining the ball valve in its path should a sudden or heavy rush occur, a guide or cage is provided. This cage also affords protection to the ball valve against wilful tampering from outside and is employed to limit the rise of the ball in order that the outlet may not be completely closed by the valve. A number of these storm-water separators are now in operation in Madras. It is found that they give very satisfactory service provided the silt-pits and gratings are regularly and properly cleaned.

Elimination of silt and rubbish.

221. Every type of storm-water separator at the junction of a side drain with a sewer must be provided with some method of extracting rags, sticks, leaves and other refuse and also the means of eliminating the silt. This is conveniently done by means of a suitable grating to exclude the coarse floating matter and a silt-pit to allow of the deposition of heavy grit, stones, and silt, which are carried into the side drains whenever it rains. A suitable arrangement of grating and silt-pit is shown on Plate XI where a curved grating of a type especially designed to deal with Madras refuse which is of such a form that a considerable quantity of refuse may collect on the grating without interfering with the flow of sewage and the silt it carries in suspension. After passing through the grating, the sewage enters the silt-pit so formed that it constitutes a receptacle for silt and the like below the flow level. A diaphragm or baffle plate, which in Madras takes the form of a Cuddapah slab, built into the walls of the chamber, causes the entering liquid to flow in a downward direction, and materially assists the settling of silt. The silt-pits are substantially covered and yet are readily accessible for cleaning. Square corners are avoided and the bottoms are rounded in such a manner that the silt will fall readily towards the cleaning scoop. Small platforms with curbs and draining gaps are provided on to which to draw the sticks and large refuse collected by the grating. The silt-pits are intended to be emptied by a cart pump provided with a flexible suction tube and silt nozzle.

House Connections.

House connection for houses with first-class type of drainage.

222. The sewer connections of houses provided with the first-class type of drainage will follow the usual European lines. Where necessary, separate rain-water drains will be laid to ensure the exclusion of the rain-water from the sewer. Disconnecting chambers, modern intercepting siphon traps, air inlets, silt-catchers, etc., will of course be provided. A type example of these connections is illustrated on Plate XII which is self-explanatory and need not be described in detail.

The conditions with which first-class house drainage must comply, and the methods of connecting to sewers are clearly specified in the proposed bye-laws given in Chapter XXI and are illustrated on Plates XXV to XXXII, they need not be repeated here.

House connection for houses with second-class type of drainage.

223. Much more important to Madras as a whole at the present time are the connections for houses having the second-class type of drainage. A great deal of thought has been devoted to overcoming the defects of the present form of connection, and, as a result, the method now to be described has been adopted.

Two types of connection for houses with open drains are shown on Plates Nos. XII and XIII. In both cases the connection begins with a 4-inch pipe of stoneware or cast-iron according to circumstances. Starting on the inside of the house wall where it is protected by a grating of special design, this pipe will convey the sewage to the silt-catcher whence, after being deprived of its silt, it will pass through the siphon trap and into the 4-inch stoneware pipe which is fitted with a cleaning arm. The 4-inch pipe will be laid at a minimum gradient of 1 in 40, and, where the sewer is at a moderate depth only, the house drain will be connected with the sewer by an oblique branch, or by a suitable junction at a manhole, so that the flow from the connection will not interfere with the flow in the sewer, but will, rather, assist it, as shown.

Vertical shafts.

224. In narrow streets where the depth of the sewer below ground is 6 feet or more, and in wide streets where the sewer is deep, a vertical down pipe will be used as shown on Plate XII.

The advantage of this vertical pipe is that it enables the connection to be laid as shallow as possible and thereby diminishes the considerable risk of damage to houses in the narrow streets that abound in Madras. At the top of the vertical pipe is a double access and test junction. The object of this junction is to facilitate cleaning and also to enable a water pressure or smoke test of the connection to be easily made by passing a stopper through the junction into the house connection. Where suitable, double junctions will be used so that two houses may be connected to the same vertical pipe. In a few cases as many as four houses may be connected to the same pipe by using two double junctions at different levels. A considerable saving is therefore effected by the adoption of these vertical down pipes.

Exclusion of silt.

225. Apparatus for excluding silt from the sewers is greatly needed. To insure that no silt, or only a negligible quantity, shall enter from the house drains, a "silt catcher," or silt trap has been designed. This will be placed at the head of every house connection.

The silt catcher consists of a steel bucket fixed in a masonry pit on the house drain. It is fitted with a diaphragm which passes across the bucket and extends 6 inches below the top of the bucket and 5 inches above. The sewage from the house drain flows over the rim of the bucket, strikes the diaphragm and passes in a slow stream under it. It rises still more slowly for the area of the outlet side is greater than that of the inlet side. The silt settles and accumulates at the bottom of the bucket, while the liquid flows over the rim on its way to the siphon trap. If left to itself, the silt will gradually fill the bucket up to the bottom of the diaphragm. It should be emptied regularly, before it reaches this level, but if neglected, the silt will accumulate on the inlet side only until the inlet side is deeply silted up Filtration of the liquid through the silt then becomes slow, and the incoming sewage backs up against the upper part of the diaphragm until it overflows through the tell-tale hole into the road or ditch, and indicates clearly to every one that the bucket is in urgent need of attention.

There are two alternative methods of fixing the silt catcher. In one where the fall to the sewer is only just sufficient, a separate chamber is provided as shown in Plate XIII. In the other where there is ample fall, the silt

catcher is placed over the siphon trap as shown on Plate XII. While both methods of fixing have proved satisfactory, the latter is preferable where the conditions permit, because the cost is slightly less, and the silt cannot get under the bucket so as to prevent it sitting properly.

Cleaning arm.

226. In the old type of connection, a stoppage of the pipe leading from the siphon to the sewer is not uncommon. When it occurs in the old type of house connection, it is necessary to dig down to the pipe and break it open; a proceeding which is both expensive and unsatisfactory, because it is difficult to make anything but a poor repair to the pipe, once it is broken. The road surface also is damaged.

The fault lies in the absence of a cleaning arm; and a more up-to-date pattern of siphon trap provided with a cleaning arm would be a great improvement. As, however, there were no less than 15,000 siphons of the old type in stock, for which Rs. 64,000 was paid, it was decided that they must be used if possible, and to that end a junction is now inserted next to the siphon, as shown on Plates XII and XIII. This allows cleaning rods to be introduced and forms an effective cleaning arm. The stopper of the cleaning arm is sealed with weak mortar, to allow ready removal.

Provision for testing house connection.

227. On house connections a vertical shaft will be provided with special access junctions referred to in paragraph 222, which will provide means for the introduction of a stopper or a bag for testing under pressure with water. In the case of connections where there is no such vertical shaft, the testing will also be carried out by means of a bag which will be inserted from the house side where the length of the connection is not more than 10 feet. Where the length exceeds 10 feet, a square junction will be inserted next to the sewer, so that a bag can be introduced and the connection tested. This testing is very desirable as it ensures a high standard of work. In the absence of such a test workmen are likely to become careless and the standard of work suffers.

Number of house connections.

228. Some difficulty was experienced in estimating the number of houses for which connections will be required. On the following page is a statement showing what connections have been provided in the different divisions:—

Statement showing the number of houses connected to the existing drainage system in each division and the total number of houses provided for in the new scheme.

Number of Division.	Number of inhabited houses in 1911 of rental above Rs. 9 per mensem.	Number of houses connected to drainage system up to 1911.	Number of houses ultimately proposed to be connected in 1961.
1	1,434	...	1,180
2	3,203	...	2,720
3	1,307	...	1,100
4	2,076	...	1,750
5	2,375	...	2,050
6	2,411	...	2,300
7	3,272	...	3,200
8	2,611	...	00
9	1,432	...	1,300
10	1,256	...	1,300
11	2,881	...	3,300
12	2,063	1,374	3,000
13	1,665	1,373	3,000
14	759	...	200
15	1,706	289	2,400
16	2,036	1,573	2,500
17	3,718	1,273	4,200
18	3,434	2,748	4,200
19	2,636	2,191	3,300
20	1,659	985	2,000
Total for whole city.	43,934	11,806	47,400

CHAPTER XII.

LATRINES AND NIGHT-SOIL DEPÔTS.

Latrines—229. Latrine, type B. 230. Latrine, type A.

Night-soil Depots.—231. Need for Night-soil Depôts. 232. Night-soil Depôts proposed. 233. Saving anticipated by adopting proposed Night-soil Depôts. 234. Cost of Night-soil disposal. Present expenditure. Estimated expenditure.

Latrines.

Latrine, type B.

229. Two types of latrines have been evolved for use in Madras. In the superior type A, there is a separate compartment with either a European W.C. or an Indian squatting basin provided with siphon trap and separate flushing cistern. This type of latrine will follow very much the lines of European latrines. It is illustrated on Plate XV. It is recommended as [illegible] and sanitary, and suitable for educated and intelligent people who will give it the slight amount of attention that is required to keep it in good order. This type is almost universal in England and America.

Latrine, type A.

230. A cheaper form of latrine which is being used successfully in Madras, both for public latrines and for factories and large offices, is of an automatic flushing type, the flush being provided either by a tipping bucket or by a siphonic flushing cistern. Separate compartments are provided because from numerous enquiries, it has been concluded that Indians appreciate privacy in these matters as much as Europeans, and it is important to encourage a sense of decency and a desire for good sanitation, especially among the class that use public latrines. The arrangement of this type is shown on Plate XIV which is self-explanatory. The latrines are divided into compartments, all opening on to a common passage. Separate accommodation is provided for each sex.

As the result of experiment, the sizes of the compartments have been fixed at 2 feet 6 inches square. The positions for taps, foot places, hoppers, and doors have also been determined by experiment. Short automatic swing-to doors of light teak boarding will give privacy. The tops of the doors are 4 feet 9 inches high, but the doors themselves are only 3 feet 9 inches deep and 12 inches above the floor. Owing to the limits of the latrine corridor, no one can see too much either over or beneath these doors except by unusual effort. On the other hand, it is easy to ascertain whether a compartment is occupied or not. The user on entering the latrine pulls open a pair of these small doors, which swing to gently behind him, he then finds his feet in position on the only standing room in the compartment. Facing him, but only 12 inches above floor level, is a small automatic water tap. While a person is using the latrine, this tap comfortably supports the right hand, leaving the left hand free

to wash with. These washings fall on a narrow trough-like area and cleanse it of urine. The excreta passes into the 6 inch covered pipe channel which passes under each compartment. The pipe is laid dead level, and by means of a small and suitably shaped cement fillet a slight depth of water is maintained in the pipe. This is sufficiently deep to prevent the excreta adhering to the pipe, but is too shallow for splashing to be produced. The user of the latrine having washed, stands up, steps into the passage, and the doors swing to again. The ablution tap closes itself automatically when the hand is taken from it. Heretofore brass taps have been used, but an effort is being made to obtain a cheap iron tap. In some cases the 6-inch stoneware pipe drain is flushed clean by an automatic siphonic cistern ; in other cases, by the waste water from the drinking fountain and washing place, which, as will be seen from Plate XIV, is in the open air, at one end of the building, but quite outside it. Before entering the flushing cistern, the waste water is passed through a silt-catcher to free it from silt which may have been used for cleaning pots, or brought on to the platform by the feet of those using it. From the silt catcher the clear water passes into a tipping box, which discharges its contents, almost instantaneously, when it is filled up to a pre-determined point ; and rights itself again immediately the discharge is completed.

The frequency of tipping, and consequent flushing depends on the rate at which [illegible] is wasted at the washing place. This is generally sufficiently rapid at all hours of the day, but, if at any time more flushing is desirable, it can be secured by turning on one of the public taps for as long as may be necessary. This would be done by the attendant who would be responsible for the cleanliness of a number of latrines.

Night-soil Depots.

Need for Night-soil Depots.

231. The conservancy of night-soil is very insanitary, objectionable, and out of date method of removing fæces. The smell produced by a string of night-soil carts passing through the streets is extremely nauseating. Moreover, the trenching grounds have to be removed from most of the densely-inhabited areas, that the expense of this method of dealing with night-soil is very great. The Health Officer estimates it to be Rs. 1,30,000 per annum. For these reasons it is highly desirable to do away with the trenching grounds. Excreta should, of course, be flushed into a sewer within a minute or two of deposition ; it then travels forward aided and enveloped by an allotted amount of water. A good many years must pass, however, before night-soil conservancy can be abolished in Madras. In the meantime, in order to dispense with the present objectionable and expensive method of dealing with night-soil, depôts where the night-soil may be introduced into the sewers are recommended.

Excreta collected in a cart should never be put directly into a sewer, because it is not sufficiently liquid to flow easily ; in Madras there is a strong additional reason, for the scavenger, when collecting, picks up with the excreta quantities of sand and silt, mingled with fragments of brick and mortar, sticks, stones, leaf plates, ashes, tin cans, and other refuse, that should on no account be allowed to enter a sewer.

Drawing No. 94 shows a depôt designed specially to deal with Madras night-soil. The conservancy cart is backed up to one of the two receiving

places, and is there tipped ; the excreta falls directly on to a cast-iron grating, the surface of which is about 2 feet below ground level in order to prevent splashing, an abundant stream of water from a pendant flexible jet-piece is directed into the cart, which is sluiced clean ; the cart then moves away and the jet is directed on to the deposited excreta, quickly forcing it down through the $1\frac{1}{2}$-inch spaces between the bars. In this way, the excreta is at once separated from all large refuse such as sticks, cans and leaf plates. This refuse is left on the bars, from which it can be removed easily by a proper rake, adapted to draw the rubbish up the masonry slope on to the floor. It is then lifted into a cart and sent to the destructor ; or a small single cell destructor could be easily attached to a depôt, if desired. The excreta, as it is driven by the water jet through the grating, becomes broken up, mingled with water, and reduced to a fairly thin consistency. In this state it falls into a smooth cemented shoot, which promptly delivers it, through the division wall, into what may be called the "flushing invert." This invert is a wide channel, having a narrow rounded bottom sloping quickly towards the inlet to the sewer. The lower portion of the invert is occupied by a series of narrow cast-iron gratings, of cross bars spaced $\frac{3}{4}$ of an inch apart ; the cemented invert is continued at a lower level, beneath this long narrow grating. When a considerable quantity of sluiced and screened night-soil has collected in the invert trough, and after, if needed, it has been stirred up (from the convenient standing platform provided), a self-closing valve is held open to give direct access into a sewer, and at the same time the flushing chamber is brought into action at the top end of the trough. The whole mass of excreta, in a liquid state, then pours into the sewer and is carried away. All refuse that escaped the large bars in the receiving places will now be caught on the long narrow grating in the bottom of the cemented trough, from which it can be readily drawn up by rake on to the floor of the depôt.

A pit to intercept sand and silt is also provided, so that nothing but water and night-soil may enter the sewer.

The carting floors are of well dressed and grouted stone pitching which is sloped to the trough to facilitate cleansing ; the mixing floor will be of concrete, similarly sloped to assist washing. All corners are rounded, and every precaution has been taken in the design to ensure sanitary conditions, and to reduce smell, as much as possible, in the night-soil depôts. A cast-iron curb imbedded in concrete, is provided for each receiving place, in order to prevent damage from cart wheels. The jets are to be controlled by small simple hand wheel valves. The supply pipes to jets and flushing tank are arranged so that no fouling is likely to occur to the water mains, under the existing conditions of intermittent supply, and if required an overhead storage tank can be included.

Night-soil Depots proposed.

232. One such Night-soil Depôt has been erected in Kistnampet. It has been working for two years and is pronounced by the Health Officer to be so successful *that he wishes* others installed so as to govern the whole of Madras.

Three or four Night-soil Depôts properly arranged would ensure that no portion of the closely built-up areas should be more than a mile and a half from a depôt.

The plan (Plate XVI) facing 121 page shows suitable positions for three such depôts.

"A" is the existing depôt near Ice House Road Pumping Station. It at present deals with the night-soil from Divisions 17 to 20. The yellow circle shows the area included within a radius of 1½ miles, and the area coloured yellow indicates what might go to this depôt.

The proposed second depôt would be placed near the Purasawakkum Pumping Station at the point marked "B." The blue circle shows the area which will be 1½ miles from this depôt.

"C" is the proposed position of the third proposed depôt. This is near the Rayapuram Pumping Station. The red circle shows the area within 1½ miles of this depôt and the area coloured red is that which would be governed by this station.

An additional Night-soil Depôt at the point shown "E" would be very useful as it would shorten the distance which night-soil from Egmore, Chintadripet and parts of Triplicane would have to be conveyed and it would also relieve "A" and "B" of a good deal of night-soil, which they would otherwise have to dispose of.

The position of "E" is close to the Lang's Garden Pumping Station. The problem of preventing it being a nuisance has been considered, and it is believed that the chimney of the existing pumping station might be used, with advantage, to prevent the smell. The Night-soil Depôt would be enclosed, as much as possible, in such a manner that the chimney would induce good draught and carry off the foul gases to be released at a high elevation where they would produce no nuisance.

It is believed that by these means a depôt at Lang's Gardens might be constructed so as not to be a nuisance in itself. But before it is decided to erect a depôt here, the question of preventing the nuisance that the night-soil carts are likely to cause should be carefully considered.

Another site where a Night-soil Depôt may be placed in future is the point marked "D" which is close to the proposed new pumping station for South Mylapore It is not intended to construct this South Mylapore Pumping Station for some years to come and it is not considered that Nightsoil Depôt "D" is necessary at present. The following table gives particulars respecting these proposed Night-soil Depots :—

Night-soil Depôt.	Position.	Divisions governed.	Approximate present population.
"A"	Near Ice House Road Pumping Station	16 to 20	167,000
"B"	Near proposed Purasawakkum Pumping Station ...	11 to 15	131,000
"C"	Near Rayapuram Pumping Station	1 to 10	215,000

If an additional Night-soil Depôt were fixed at "E" it could deal with the Divisions Nos. 13, 15, 16 and 17 having an approximate total population of 100,000, and the Night-soil Depôts at "A" and "B" would be relieved accordingly. The Night-soil Depôt at "D" would relieve the Night-soil Depôt at "A" of a population of about 22,000.

These Night-soil Depôts will mean that practically no portion of any thickly-inhabited area will be outside a circle of two miles radius from a Night-soil Depôt.

Saving anticipated by adopting proposed Night-soil Depots.

233. From a statement supplied by the Health Officer, it is estimated that the saving in the cost of the disposal of night-soil by the adoption of pail depôts will be some Rs. 25,000 to Rs. 30,000 per annum (*see* tables on pages 124, 125). From the same statement it will be seen that the cost of the disposal of night-soil is estimated by the Health Officer at Rs. 1,30,039. Thus the saving effected is about 25 per cent. When night-soil is wholly disposed of by the Water Carriage System, this additional revenue of 1·3 lakhs of rupees will accrue to the Corporation.

Cost of Night-soil disposal.

234. The two following statements give the cost of night-soil disposal: —

Statement A shows that the cost at present with only one Night-soil Depôt, remainder trenched, amounts to ...	Rs.	1,30,000
Statement B shows that with trenching abolished and Night-soil Depôts so arranged that no closely built-up area is more than two miles from a depôt, the cost would amount to ...	„	91,500
Saving by the introdu[illegible]	„	38,500

or nearly 30 per cent.

These estimates are prepared upon the figures supplied by the Health Officer, who, from his experience at Kistnampet, is anxious to have further Night-soil Depôts constructed.

Two designs for such depôts have been prepared and detailed estimates of their cost are given in Volume II, Section C, pages 187 and 188 to be checked. The cost of these depôts works out at—

For type A, including roof	Rs.	3,800
For type B, a cheaper form, without roof	„	2,100

No amount has been included in the general estimates on account of these depôts.

NIGHT-SOIL DISPOSAL.

A—Present Expenditure with one Night-soil Depot for Divisions 17—20. Remainder of Night-soil trenched.

	Particulars.	No.	Rate.			Monthly.			For 12 Months.			Remarks.
			RS.	A.	P.	RS.	A.	P.	RS.	A.	P.	
1	**Collection—**											
	Latrine Men	54	6	8	0	351	0	0				
	Do. Men and Hand-cart Men ...	95	6	0	0	570	0	0				
	Do. Women ...	50	4	8	0	225	0	0				
	Do. do.	46	3	8	0	161	0	0				
						1,307	0	0	15,684	0	0	
2	**Removal—**											
	Driver Maistries ...	8	9									
	Drivers											
	Reserve Drivers ...	16										
	Fodder ...	257	20	0	0							
	Contingencies		...	..	...	300	0	0				
						7,327	0	0	87,924	0	0	
	Gra.n Depôt Staff		...	...	...	...	...	...	676	0	0	
	Purchase of Bullocks		...	...	...	...	...	...	3,000	0	0	
	Maintenance of Carts		...	...	...	...	...	...	5,000	0	0	
	Disposal—											
	Labour at Korukupet		...	...	..	351	0	0				
	Do. at Brick Kiln Road. ...		...	..	...	146	0	0				
	Do. at Nungambaukam. ...		...	...	...	14	0	0				
	Do. at Ice House Road Pail Depôt		..	...	..	253	0	0				
	Do. at Mylapore Wharf. ...		...	...	...	33	0	0				
						797	0	0	9,564	0	0	
	Contingencies		...	...	...	...	...	...	1,516	0	0	
4	**Supervision—**											
	Conservancy (General) ...		...	...	..	...	...	...	11,002	0	0	
	Maintenance of Bullocks ...		...	...	...	...	...	...	2,530	0	0	
	Night-soil Depôts ...		...	...	...	...	...	...	1,068	0	0	
									1,37,964	0	0	
	Deduct income from sale of Manure ...		...	...	...	...	...	...	7,925	0	0	
	The net Expenditure ...		...	...	...	...	...	...	1,30,03	0	0	

Taking the population as 520,000, average cost per head per annum is 4 annas.

NIGHT-SOIL DISPOSAL.

B—Estimated Expenditure with Night-soil Depots so arranged that no closely built-up area is more than 2 miles from a Depot.

	Particulars.	No.	Rate.			Monthly.			For 12 Months.			Remarks.
			RS.	A.	P.	RS.	A.	P.	RS.	A.	P.	
1	**Collection—**											
	Latrine Men	54	6	8	0	351	0	0				
	Do. Men and Hand-cart Men ...	95	6	0	0	570	0	0				
	Do. Women ...	50	4	8	0	225	0	0				
	Do. do. ...	46	3	8	0	161	0	0				
						1,307	0	0	15,684	0	0	
2	**Removal—**											
	Driver Maistries ...	8	9	0	0	72	0	0				
	Drivers	121	7	0	0	847	0	0				
	Reserve Drivers ...	8	8	0	0	64	0	0				
	Fodder	129	20	0	0	2,580	0	0				
	Contingencies	...	..	...	...	150	0	0				
						3,713	0	0	44,556	0	0	
	Gram Depôt Staff ...	...	...	...	...	...	...	...	340	0	0	
	Purchase of Bullocks ...	...	...	...	...	...	...	...	1,800	0	0	
	Repair of Carts ...	...	...	...	...	...	...	...	3,000	0	0	
3	**Disposal—**											
	Royapuram Station Pail Depôt.	...	...	...	...	220	0	0				
	Purasawakkum Station Pail Depôt.	...	...	...	...	200	0	0				
	Lang's Gardens Station Pail Depôt.	...	...	...	...	140	0	0				
	Ice House Road Station Pail Depôt.	...	...	...	...	220	0	0				
						780	0	0	9,360	0	0	
4	**Supervision—**											
	Conservancy (General) ...	...	...	...	...	...	...	...	11,002	0	0	
	Maintenance of Bullocks ...	...	...	...	...	...	...	...	2,530	0	0	
	Night-soil Pail Depôts ...	...	...	...	...	...	...	...	3,270	0	0	
	Total ...	...	...	...	...	...	...	...	91,542	0	0	

Taking the population as 520,000, average cost per head per annum is 3 annas.

CHAPTER XIII.

POPULATION TO BE DEALT WITH.

235. Introduction. 236. Importance of determining growth of population. 237. Growth of population of Madras City as a whole. 238. Causes of recent decrease in rate of growth of population. 239. Removal of large bodies of men. 240. Emigration. 241. Immigration. 242. Influences affecting immigration. 243. Summary of conclusions. 244. Industrial position of Madras. 245. Past increase of population in the different divisions. 246. Different rates of increase in the different divisions. 247. Estimated populations of different divisions in 1961. 248. Tondiarpet. 249. Georgetown. 250. Perambur. 251. Vepery. 252. Nungambaukum. 253. Triplicane. 254. Mylapore. 255. Detailed estimates of population.

Introduction.

235. When the writer's Tondiarpet Drainage Report, dated June 1909, was considered by the Commissioners, he was requested to furnish detailed information of the methods that he had adopted in calculating the population that the sewers would serve. In this section the writer, in anticipation of a similar request, gives some account of the methods by which the population to be dealt with has been calculated, the data upon which the calculations have been based, and the considerations which have led to the estimated future growth of population.

As far as the writer is aware, nobody else has tried to foretell the growth of population and as such estimates are deductions from facts, and these deductions depend very largely upon personal judgment, it is desirable to present the subject in detail in order that any errors in fact, deduction or judgment, may be pointed out by those who scrutinise the proposals.

Importance of determining growth of population.

236. In connection with a drainage system where—as in the present case—rain-water is rigidly excluded the size of the pipes, the capacity of the pumps and the design of the whole system depends very closely on the population. It is therefore of the greatest importance to ascertain as accurately as possible the future growth in the population of Madras City. Not only of the city as a whole, but also of each individual district. It would, for instance, be absurd to provide for the same percentage increase in densely built-up Georgetown as in sparsely populated Perambore. If this were done, wasteful expenditure would be incurred in providing Georgetown with unnecessarily large pipes, while in a few years' time the sewers provided for Perambore would be too small.

Any works that may be constructed must be sufficiently large to supply the needs of the inhabitants as long as the works are likely to last. For instance, first-class steam pumps, similar to those recently installed at the Law College and Rayapuram Sewage Pumping Stations, are likely to give satisfactory service for 20 to 25 years. In order to determine the size of such pumps, it is necessary, therefore, to estimate the growth of the population in 25 years with as much accuracy as possible, so that, on the one hand, the pump ordered may be of sufficient size to raise all the sewage required, without replacing it till it is worn out, and on the other hand, it should not be needlessly expensive through being excessively large.

Similarly in the case of the stoneware sewers and the cast-iron pumping mains, which may be expected to last for 50 years or even more. An estimate

must be made of the population of the particular district, which each pipe has to serve, for a period of at least 50 years.

In what follows it is proposed first to consider the increase in population of the Madras City as a whole, its causes and to what extent they are likely to be modified, and afterwards to deal briefly with the growth of population in the different districts which make up the city.

Growth of population of Madras City as a whole.

237. Dealing first with the population of Madras City as a whole, the census figures are as follows :—

Date of Census.	Population of Madras City.	Increase in 10 years.	Percentage increase in 10 years.
1871	393,920	First Census.	
1881	398,777	4,857	1·23
1891	450,640	51,863	13·00
1901	509,346	58,706	13·00
1911	517,335	7,989	1·57

The change in population between 1871 to 1880 may be disregarded. The terrible famine of 1877 largely increased the death-rate of that and the following year, and rendered the figures for the decade useless as a basis for estimating future growth.

During the twenty years 1881 to 1900 there was a steady growth of population averaging 12½ per cent. per decade. Until the figures of the last census were published, this appeared to be the normal rate, and in recent estimates an increase of about 12½ per cent. per decade was generally assumed in calculating the probable future population of Madras City.

The census of 1911, however, has shown that the increase for the last decade was but 1·6 per cent. and it has become necessary to revise the previously-accepted figure.

The rates of increase during the past 40 years (1871 to 1910) are shown clearly by the curves on Plate No. XVIII, which shows by full lines of the population, both for Madras City as a whole, and also for each of the eight divisions into which the town may conveniently be divided. The dotted lines show estimated future population. This will be dealt with further on.

The curves show clearly how greatly the rate of increase has diminished during the last ten years. It is important to examine the causes of this great decline in order to foretell whether the present low rate may be regarded as normal, or whether it is likely to increase or to decrease.

Causes of recent decrease in rate of growth of population.

238. As a result of his own enquiries and of consultations with Mr. Molony, Superintendent of the 1911 Census, and with Mr. Raghaviah, the late Corporation Revenue Officer, the writer has prepared the following estimate of the effect of the causes that have operated to decrease the rate of growth of population in Madras City during the decade 1901 to 1910 as compared with previous decades. The

last column gives a forecast of the extent to which the effects of these causes are likely to be modified during the next 50 years :—

Causes.	Loss of population, 1901—10, compared with 1891—1901.	Estimated average increase per decade 1911—60 as compared with 1901—10.
(1) Removal of Troops, etc.	3,500	3,500
(2) Closing Government Workshop, etc.	5,000	5,000
(3) Harbour Works	—2,000	—2,000
(4) Emigration	2,000	—4,000
(5) Immigration	20,800	7,000
(6) Excess of deaths over births	22,600	10,000
(7) Over enumeration	2,800	*Nil.*
Total ...	54,700	19,500
Increase of population, 1901—10	...	9,300
Anticipated average rate of increase per decade, 1911—60.	...	28,800

The second column of this table explains the failure to increase during 1901 to 1910 by 54,700 as compared with the previous decade.

If to this be added the actual increase of 9,300, we obtain 64,000, which is 12·6 per cent. of the population of 1901 (509,300). This figure agrees exactly with the 12·6 per cent. which was the average increase for the previous decade (1891—1900).

The decreased rate of increase is thus accurately accounted for. Is this low rate likely to remain the normal rate? If not, to what extent is it likely to increase or decrease?

To answer these questions the figures in the last column have been prepared. From them it will be seen that for the purpose of making calculations for the drainage system, the writer has thought it advisable to estimate for an average increase in population of 28,800, or about 5 per cent. per decade. This is the greatest increase for which in his opinion provision need be made. The considerations which have led to this estimate will now be examined by taking in order the causes enumerated in the table.

Removal of large bodies of men.

239. *Causes* 1, 2 and 3 include the removal of large bodies of men from the Municipal limits, and the completion of large temporary works. The particular losses of population which have occurred under these heads during the past 10 years of course cannot recur. At the same time other bodies of men may move outside the city boundary. The imminent removal of the Engineering College from Chepauk to Guindy may be instanced as a case in point. These losses are not likely to be great, and probably will be neutralised by counter-balancing immigration. It will then be on the safe side,—*i.e.*, with a tendency whenever there is a doubt to over-estimate the increase—if we assume that there will be no further decrease from *Causes* 1, 2 and 3.

Emigration.

240. *Cause* 4: *Emigration to districts outside Municipal limits* is likely to continue and to increase rather than decrease, because the means of transportation are likely to become better and—compared with wages earned—to become cheaper. This, together with the increase in value of property and the rise of rents, rates and taxes within Municipal limits, will ensure the maintenance of the present rate of emigration to residential areas where living is less expensive.

Any increase in the number of emigrants will, however, be neutralised by absorption into the Municipality of those suburbs—such as parts of Perambur and Sembyam—lying just outside, where a demand for good water, drains, lighting and roads is arising, as they are becoming more and more urban in character

Immigration.

241. *Cause* 5: *Immigration* is a most important factor in the growth of the city, and in the past it has accounted for the greater part of the increase. The tendency over the whole of the civilised world is for the population to move from the country into the cities. This tendency is readily accounted for. On the one hand, the city increasingly affords conveniences and opportunities of intercourse and education, together with gaiety and luxuries, that are unobtainable in the mofussil. On the other hand, the introduction of mechanical methods has greatly reduced the amount of labour required for cultivating the land. In the west of America the engineer is rapidly taking over the control of Agriculture. Madras is no exception to the general rule, even though it be a very long way behind Europe and America.

The numbers of immigrants during the last two decades were :—

1891 to 1900	33,500
1901 to 1910	12,700

From these figures it would appear that the attractiveness of Madras City is on the wane. Since immigration in these 20 years accounted for 46,200 out of a total increase of 66,100—in other words 70 per cent. of the total increase —it is important to examine carefully the causes that are likely to influence immigration in future.

Influences affecting immigration.

242. People come into the city for the following reasons amongst others :—

(1) To earn high wages.
(2) To give their children good education.
(3) To take advantage of hospitals and other similar institutions.
(4) To satisfy their desire for social intercourse and amusement.

Immigration is also effected by —

(5) The health of the city.
(6) The existence of suitable living accommodation.

Of the influences just enumerated, the standard of wages probably affects immigration most. Wages have risen greatly in Madras City during the last decade. That they will continue to rise for many years to come is practically certain in view of the growing demand for labour for the large water, drainage, and building works recently started or projected, and on account of the foreign demand for Tamil labour for coffee, tea, rubber plantations, and other purposes.

Those who come to Madras for education are perhaps not very numerous, but they will certainly increase with the new impetus that has recently been given to elementary education.

As regards health, there is every probability that a considerable improvement will result from the introduction of the new water-supply and the completion of the new drainage works. Although the increased healthiness is not likely to be greatly appreciated within the next decade, nevertheless the benefits of an adequate water-supply will very soon be felt in those areas—such as Mylapore and Tondiarpet—where at the present time there is a serious deficiency. The medical men of Madras are now carrying on a vigorous crusade in favour of educating people of all classes to appreciate the great care which should be taken at child-birth. This crusade will have its due effect. In India, as in England and other European countries, a marked diminution of infantile mortality is bound to result from more attention to mother and child. In time the excess of deaths over births will greatly decrease until it vanishes. Madras will become a more healthy place and will on that account gain in attractiveness. This cannot, however, be expected to begin at once. Malaria has increased, and will require stringent measures to stop it. The drainage system will take some years to complete, and it will be another ten years or so before sanitary measures, now being adopted, begin to have a marked effect, and it is not likely that they will show themselves to any great extent in the next Census returns of the city. The question of health in relation to sanitation is of such great importance that is dealt with separately in Chapter XIV.

Summary of conclusions.

243. We have now considered the causes which account for the reduction in the rate of increase in population which has taken place during the last decade. The conclusions may be summarised by saying that, as far as can be foreseen, there is likely to be a small increase due to *Causes* Nos. 1 to 5, and that as the health of the city increases and the births come to exceed the deaths, there will be provided an increase in population, if there is anything for them to do.

Industrial position of Madras.

244. This leads to the consideration of the industrial position of Madras. And here it may be said at once that Madras is not likely to become an industrial centre of importance.

There is no natural fuel except wood, and there are in the hinterland no ores or minerals which, as far as can be seen at present, would repay mining on a large scale. Of late years, the prices of both coal and wood have risen, and manufactures in the future will depend largely on oil imported from outside, and on suction gas, which is best produced from imported material.

There is no indication that cotton mills are likely to develop to any great extent in Madras City. It is more likely that they will be established where power can be obtained through electricity generated by natural water-power.

A certain increase in trade may result from increased facilities afforded by the Harbour improvements, but it is difficult to see how it will be possible to increase appreciably the radius within which Madras may profitably be utilised as an import and export centre.

There are certain industries which may be expected to expand considerably, such as the manufacture of Portland cement and tiles. These will employ a considerable number of men and thus add to the population. New industries are likely to be introduced, just as recently the Indian Aluminium Company has started to manufacture aluminium goods and Messrs. Chambers & Co. to make leather.

After conferring with professional and business men of all classes, the conclusion arrived at is that there is no likelihood of any industry being started which will employ a large number of men. As the result of the most careful consideration, the writer has decided that an increase of 27·6 per cent. over the population of 1911 is the greatest which can reasonably be anticipated within the next 50 years. This figure refers to the whole of Madras.

Past increase of population in the different divisions.

245. The average for the city does not apply to every part of the city. Some areas—such as Georgetown—are already overcrowded and are not likely to increase much if at all. Other areas—such as Perambur—are only sparsely populated, and it is in these that the greatest growth may be expected.

The growth of population in each of the eight divisions during the past 40 years is shown in the following table which gives the population of the different divisions for each census and also the density of the inhabited areas of each division. The rates of increase are also given :—

Statement shewing the Population per acre and increase of Population for the eight different divisions of Madras. The figures have been obtained from Census Reports of 1871 to 1911.

Name of Division.	Tondiarpet	George-town, West.	George-town, East.	Perambur.	Vepery.	Nungambaukam.	Triplicane.	Mylapore.	TOTAL.
Number of Division.	1	2	3	4	5	6	7	8	
Inhabited area in acres ...	3,398	474	422	2,483	1,562	2,662	845	2,816	14,662
Population per acre, 1871 ...	19·1	150·8	123·5	3·9	41·6	7·2	81·6	14·6	26·8
" " " 1881 ...	18·6	163·5	121·5	4·3	46·7	7·1	84·1	13·5	27·1
" " " 1891 ...	21·0	178·0	238·1	6·1	48·7	8·1	96·2	14·6	36·7
" " " 1901 ...	24·8	188·5	143·7	9·4	55·1	9·0	111·1	16·6	34·6
" " " 1911 ...	22·4	182·7	129·9	10·1	60·9	10·1	116·3	19·3	35·3
Total population, 1871 ...	64,885	71,474	52,097	9,701	64,901	19,221	68,940	41,113	392,332
" 1881 ...	63,344	77,497	51,292	10,793	66,655	19,010	71,095	37,940	397,626
" " 1891 ...	71,509	84,385	58,296	15,250	76,052	21,590	81,288	41,109	449,479
" " 1901 ...	84,156	89,375	60,625	23,223	86,020	23,843	93,854	46,912	508,008
" " 1911 ...	75,986	86,584	54,833	24,981	95,172	26,929	98,254	54,443	517,182
Increase in population. 1901—1911 ...	—8,170	—2,971	—5,792	1,758	9,152	3,086	4,400	7,531	9,174
1871—1911 ...	11,101	15,110	2,736	15,280	31,211	7,708	29,314	13,330	124,850
Percentage increase or decrease of population. 1871—1881 ...	—2·6	+8·4	—1·6	+10·3	+2·6	—1·4	+3·1	—7·5	+1·1
1881—1891 ...	+12·9	+8·9	+13·7	+41·9	+14·1	+14·1	+14·4	+8·1	+13·3
1891—1901 ...	+18·1	+5·9	+4·1	+54·1	+3·1	+11·1	+15·5	+14·4	+12·7
1901—1911 ...	—9·7	—3·1	—9·6	+5·6	+10·6	+12·9	+4·7	+16·0	+1·8
Total percentage increase of population. 1871—1911 ...	+18·9	+20·1	+6·6	+113·9	+40·4	+36·7	+37·7	+31·0	+28·9
" 1881—1911 ...	+23·3	+11·7	+8·2	+103·6	+37·8	+38·1	+34·6	+38·5	+27·82
" 1891—1911 ...	+8·4	+2·8	—5·5	+61·7	+23·7	+24·0	+20·2	+30·4	+15·74
Average percentage increase of population per decade ...	4·75	5·0	1·6	28·5	10·1	9·2	9·4	7·75	7·2

NOTE.—In determining the density of population, the uninhabited areas, such as the Island, the Esplanades, Parks, Canals and large Irrigation tanks have been excluded. Neither the area nor population of Fort St. George are included in any of the divisions.

The map facing this page shows the eight divisions referred to above. The black figures give the populations of the several divisions as determined by the 1911 census. The red figures give the corresponding populations as estimated for 1961.

Different rates of increase in the different divisions.

246. It is interesting to note from the table given in the last paragraph that the percentage increase in population for the last 40 and 20 years, respectively, are as follows :—

Name of Division.	No. of Division.	Total percentage increase of population.	
		1871—1910.	1891—1910.
Whole City ...	...	28·9	14·5
Tondiarpet	1	18·9	8·4
Georgetown, West	2	20·1	2·8
Do. East	3	6·6	—5·5
Perambur	4	113·9	61·7
Vepery	5	40·4	23·7
Nungambaukam	6	36·7	24·0
Triplicane	7	37·7	20·2
Mylapore	8	31·0	30·4

The table shows clearly how very different have been the rates of increase of population in the different divisions. Thus while Perambur has increased its population by 62 per cent. during the last 20 years, Georgetown East has actually diminished in population by 5 per cent. during the same period. The population is increasing in all directions on the north, south and west of Georgetown. During the last decade (1901—10) there has been a check in the growth of the population in the northern divisions of the city, but this is probably only temporary. The principal increase has been in the west. In Georgetown itself the population is likely to remain stationary or even to decrease. As the wealth of the people increases, as railways and trams continue to extend more and more, and as the means of cheap and rapid transit become more available, the number of those who are obliged to live in the densely-populated areas decreases.

So it comes about that as a general rule, and as would be expected, the rate of increase is greatest in the most thinly-populated areas, and is least in those districts where the density is greatest. Thus for the 40 years ending 1910, sparsely-populated Perambur increased by 114 per cent., whereas crowded Georgetown East shows a gain of but 6·6 per cent. These facts show how erroneous would be deductions based on the assumption that the increase in population will in the future be uniform all over the town and how important it is to estimate the growth of each division separately. In like manner it is highly desirable to continue the sub-division to the smallest unit for which reliable figures are available in order that every sewer may be correctly designed for the population that it has to serve.

Estimated populations of different divisions in 1961.

247. To make the figures clearer, they have been plotted as curves on the diagrams forming Plate XVIII. Unfortunately, the first part of each curve between 1871 and 1881 is of little value because of the terrible famine which occurred between those dates; and for the purpose of foretelling the future growth of population, these portions of the curves have been discarded. The curves show the populations of the different divisions at the dates of census 1871, 1881, 1891, 1901 and 1911. These curves, produced as dotted lines, are used for calculating the future population in the year 1961 which is as far into the future as it is profitable to estimate for the drainage scheme now proposed. From these curves we get the following figures for the increases in the different divisions :—

Estimated increases in population in the different divisions.

No. and Name of Division.	Population in 1911.	Estimated increase in 50 years.	Estimated population in 1961.	Percentage increase per decade on population of 1911.
1. Tondiarpet ...	75,986	23,514	99,500	6·20
2. Georgetown West ...	86,584	8,516	95,100	2·00
3. Do. East ...	54,986	4,314	59,300	1·60
4. Perambur ...	24,986	27,619	52,660	22·10
5. Vepery ...	95,172	24,828	120,000	5·20
6. Nungambaukum ...	26,929	9,571	36,500	7·10
7. Triplicane ...	98,254	13,746	112,000	2·80
8. Mylapore ...	54,443	30,557	85,000	11·20
Totals ...	517,335	142,665	660,060	5·50 (for whole city)

In order to justify these figures for the distribution of the future growth of population in different divisions, they will now be very briefly dealt with in order.

Tondiarpet.

248. *Division No.* 1 : *Tondiarpet.*—Owing to erosion which is taking place on the coast, and on account of the area occupied by the Corporation Sewage Farm, the increase in population in the eastern portion of this division is likely to be small. The central and western areas are, however, likely to increase considerably owing to increased facilities for getting backwards and forwards to Georgetown, which will be granted at an early date, when the extension of tramways in this part of the city is completed. Further, the introduction of an ample water-supply, and a proper drainage system, will greatly improve the healthiness of this area, which at present has the unenviable notoriety of possessing the highest death-rate in Madras.

Georgetown.

249. *Divisions* 2 *and* 3, *Georgetown,* are not likely to increase much. In fact they may decrease. As means of communication become better, the inhabitants of Georgetown will tend to emigrate to less crowded districts.

Although it is possible that larger and higher buildings will be erected in this part of the city, nevertheless when we look at density as given in the table on page 133, where we see that Georgetown, west, has an average density of about 183 inhabitants per acre as against 116 of the next densest and 61 of the third densest, it becomes evident that the population is likely to move elsewhere.

Perambur.

250. *Division No.* 4, *Perambur*, has considerable open spaces, and means of communication with this district are good and are likely to improve. It shows a greater percentage of growth in the past than any other district, and there is every probability that in the future it will continue to show the greatest rate of increase.

Vepery.

251. *Division No.* 5, *Vepery*.—This district has shown a considerable increase during the last 40 years amounting to 40 per cent., and in the last decade it has increased by as much as 10½ per cent., despite the fact that the Gun Carriage Factory and other Government works have been closed during that period. There is still a considerable area where houses can be built and it is likely to increase considerably in the immediate future as a place of residence for the workers both in Georgetown and in Vepery itself.

Nungambaukum.

252. *Division No.* 6, *Nungambaukum*.—This area is mainly occupied by bungalows in large compounds. These compounds are, however, being steadily divided up, and it is likely that this process will continue, and that it will become more closely built up and that the population will continue to increase steadily as it has done in the past.

Triplicane.

253. *Division No.* 7, *Triplicane*.—Triplicane is already densely built over in many parts and no considerable growth is to be expected. In fact, seeing that it has a density of 116 inhabitants per acre (second only to Georgetown), it is likely that some emigration will take place into Mylapore on the south and Nungambaukum on the west. It has been thought advisable to allow for a small increase in population due to building over the unoccupied areas to the south of the division—an operation that has already commenced.

Mylapore.

254. *Division No.* 8, *Mylapore*.—This area has shown a steadily increasing rate of growth during the last 40 years and is exceptional in that the growth during the last decade was greater than that during any previously-reported decade. Moreover, the increase of 16 per cent. during the last decade was greater than that of any of the other divisions. Seeing that the area includes Adyar, where there are still large open spaces to which the wealthier inhabitants of Madras are likely to migrate, as they are crowded out of Nungambaukum and Egmore, it is probable that this area will continue to increase and an allowance has been made for an average rate of 11 per cent. per decade, which is greater than that of any other division, except Perambur.

Detailed estimates of population.

255. In working out the drainage system, it was necessary to go into a great deal more detail than this. In the first place, the city was considered in 20 divisions instead of 8, and again it was found necessary to consider many

divisions in their separate circles of which there are 113, and in many cases, each individual circle had to be divided up into inhabited areas and open spaces, and the probable increase of each portion was separately estimated. In Appendix No. 3 are given tables from which the calculations of the populations of the different drainage divisions may be checked.

The map facing this page shows the 20 divisions referred to. The black figures give the population for each division as determined by the census of 1911, and the red figures the estimated populations in 1961.

The following table gives the same information and also the estimated rates of increase in population :—

Estimated increase of population for the 20 *divisions of Madras taken for the* 50 *years* 1911 *to* 1961.

Division.	Population as per Census of 1911.	Estimated increase of population for 50 years.	Estimated population for 1961.	Estimated percentage of increase for 50 years.	Average percentage of increase per decade.
1	20,318	2,032	22,350	10%	2%
2	40,635	12,191	52,826	30%	6%
3	15,120	5,292	20,412	35%	7%
4	14,564	1,165	15,729	8%	1·6%
5	19,179	1,534	20,713	8%	1·6%
6	22,473	1,798	24,271	8%	1·6%
7	37,065	3,707	40,772	10%	2%
8	28,585	2,859	31,444	10%	2%
9	20,937	2,094	23,031	10%	2%
10	24,979	27,477	52,456	110%	22%
11	41,523	10,796	52,319	26%	5·2%
12	29,776	7,742	37,518	26%	5·2%
13	23,717	6,166	29,883	26%	5·2%
14	11,751	5,992	17,743	51%	10·2%
15	15,180	7,742	22,922	51%	10·2%
16	26,752	2,675	29,427	10%	2%
17	38,643	5,410	44,053	14%	2·8%
18	32,851	4,599	37,450	14%	2·8%
19	34,358	18,897	53,255	55%	11%
20	20,254	11,139	31,393	55%	11%
Total ...	518,660	141,307	659,967	...	...
			Say 660,000		

For particulars of populations of circles included in the divisions, *see* Appendix No. 3.

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CHAPTER XIV.

DEATH-RATE AND DRAINAGE.

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256. Introduction. 257. Death-rate increasing. Birth-rate and death-rate per decade. 258. Deductions from tables and diagram. 259. Necessity for removing products of life processes. 260. Relation between drainage and death-rate. 261. Conclusion.

Introduction.

256. The importance of healthiness of the city has already been briefly touched upon in the last chapter dealing with the question of the increase of population. The continuity of the argument would have been interrupted if any account of the health of the city had been introduced at that point. As, however, the information which the writer has been able to collect appears to be of sufficient interest to merit its inclusion in this report; it is dealt with separately in the following paragraphs :—

The importance of drainage as a factor in the health of Madras is alone considered here. No attempt has been made to deal with other factors affecting the health of the city. They do not lie within the province of the writer, but are matters which concern the Health Officer.

Death-rate increasing.

257. That the high death-rate which at present exists is due in a large measure to the unhealthy condition of the city brought about by inefficient and, in some places, total absence of a proper drainage system there can be no doubt.

In spite of greatly increased scientific knowledge and in spite of a greatly improved medical service the healthiness of the city has not increased but has rather decreased. To ascertain this fact the birth and death-rate returns have been carefully studied, and the accompanying table which gives the birth and death-rates for the forty years 1871 to 1910 has been prepared :—

BIRTHS AND DEATHS, 1871 to 1910.

Year.	Total Number of		Rate Per 1,000 of Population.		Remarks.
	Births.	Deaths.	Births.	Deaths.	
1871	8,342	13,035	20·9	32·7	Calculated on population given by 1871 Census.
1872	7,986	14,018	20·1	35·2	
1873	9,165	14,609	23·1	36·7	
1874	10 826	14,760	27·2	37·1	
1875	10 099	14,169	25·4	35·6	
1876	11,389	15,759	28·6	39·6	
1877	14,038	46,617	35·3	117·2*	*Increased death-rate due to famine.
1878	14,763	18,912	37·1	47·5*	
1879	16,261	13,803	40·9	34·7	
1880	15,679	14,907	39·4	37·4	
1881	15,476	15,487	38 9	38·9	Calculated on estimated population of each year.
1882	16,523	14,169	40·9	35·0	
1883	16,069	15,882	39·2	38·7	
1884	15,809	20,123	38·1	48·5	
1885	15,768	14,925	37·5	35·6	
1886	15,720	14,699	36·9	34·6	
1887	16 287	16,192	37·8	37·3	
1888	15,980	15,439	36·6	35·4	
1889	16,349	17,086	37·0	38·6	
1890	17.569	17,194	39·3	38·5	
1891	18,061	23,808	39·9	52·6	
1892	16,659	20,847	36·4	45·5	
1893	18,221	18,584	39·3	40·0	
1894	17,062	16,542	36·3	35·1	
1895	19,137	17,052	40·3	35·8	
1896	18,684	17,131	38·8	35·6	
1897	18,702	16,086	38·4	33·0	
1898	18,694	20,286	38·0	41·2	
1899	18,220	17.248	36·6	34·6	
1900	20,672	20,937	41·0	41·5	
1901	18,872	28,031	37·0	55·0	
1902	17,743	21,395	34·7	41·9	
1903	19,830	19,205	38·7	37·5	
1904	20,439	19,305	39·9	37·7	
1905	23,263	30,060	41·4	58·6	
1906	18,608	23,749	36·2	46·2	
1907	19,808	20,638	36·5	40·0	
1908	19 980	22,285	38·7	43·1	
1909	18,981	19,354	36·7	37·4	
1910	19,340	20,312	37·3	39·2	

Birth-rate and death-rate per decade

From the figures in the above table it is difficult to perceive the general trend on account of the great variation from year to year If, however, the

average of each decade is taken, it will at once be seen what has taken place. The figures per decade are as follows :—

Decade.	Birth-rate.	Death-rate.	Excess of death-rate over birth-rate.
1871—1880 ...	29·8 ...	37·4 ...	7·6
1881—1890 ...	38·2 ...	38·1 ...	0·1
1891—1900 ...	38·5 ...	39·4 ...	0·9
1901—1910 ..	37 7 ..	43·6 ...	5·9

The deaths during the famine year 1877 have been neglected in preparing these averages because the conditions which produced the famine were exceptional and with the improved means of transport now available, these conditions are not likely to recur.

Deductions from tables and diagram.

258. In order to bring out quite clearly the variations in birth and death-rates they have been plotted on the diagram, Plate XX facing this page. From this diagram, coupled with the figures, it will be distinctly seen that—

(1) There has been very little change in the birth-rate during the last thirty years, though there has deen a slight drop during the last decade.

(2) There has been a slow but steady increase in the death-rate.

(3) The excess of death-rate over birth-rate which had practically vanished for the twenty years 1881—1900 has again become marked during the last decade.

Of these facts the most striking, and that which most nearly concerns us, is the steady increase in the death-rate. This contrasts very unfavourably with the steady decline in the death-rate of England and Wales, during the same period as shown by the heavy dotted black line—

The average death-rates per 1,000 for each decade are—

	1871—80.	1881—90.	1891—1900.	1901—10.
England and Wales ...	21·4 ...	19·3 ...	18·5 ...	15·2
Madras City ...	37·4 ...	38·1 ...	39·4 ...	43·6

The explanation of the high Madras death-rate is not far to seek, it is too obvious to those who understand on what the health of a city depends.

Necessity for removing products of life processes.

259. Life in the crowded parts of Madras is coming within the scope of the law that the life of all organisms comes to an end when the products of their growth are not removed with sufficient rapidity and thoroughness.

Indian gentlemen have told the writer that those prophets and seers, to whom they look for wisdom and guidance, have laid down that nature, the great purifier, will do all that is necessary, that sewage disposal should be left to nature, and that if any artificial methods are substituted, then disaster is sure to follow.

To gentlemen with such views it may be pointed out that their seers were quite right in advocating the agency of nature to remove the foul poisonous filth which results from human life, but in order to give nature fair play, it is necessary to remove these products of human growth from the highly artificial and quite unnatural conditions which we see in the crowded parts of our city. It is a universal law of nature, that the products of the growth of any organism

are fatal to that organism. It is true of the highest and the lowest, and it is as true of human beings as it is of the humble bacilli each some $\frac{1}{20,000}$ inch in length, who die in such large numbers from the poison which they themselves produce.

As the Hindu seers lay down, we must obey the behests of nature. This has not been done in Madras, and the result is that—in spite of freedom from serious epidemics of plague and cholera which yearly visit less favoured cities—the death-rate of Madras has steadily grown during the last forty years and for the last ten years it averaged 43·6 per thousand.

If this rate is to be lowered—as it should and must be lowered—it will be necessary to take to heart the lessons which nature teaches, and as quickly as possible to get rid of the waste products of human life processes.

We must have a first class system of drainage, and abandon the custom, dating from the earliest days of Madras, of adding a continuous stream of solid and liquid filth to the subsoil of the city

In addition to the improvement of health which will result from improved sanitation, it may confidently be asserted that there will be a large reduction in the present exceedingly high rate of infant mortality.

Relation between drainage and death-rate.

260. In order to ascertain whether or not any connection could be traced between death-rate and drainage, the death-rates from 1906—10 of the 20 divisions of the city were tabulated. It was atonce obvious that the badly drained areas had the highest death-rates and those areas where the drainage was best had the lowest death-rates.

It may be argued that this is only a coincidence, and that the determining factor in the health of the city is something other than drainage.

To determine this point two other factors—density of population and water-supply—were considered. Both undoubtedly affect health very materially. With a deficient water-supply there must be ill-health. With a high density of population fresh air and sunshine are absent from many of the living rooms of the people.

In a city like Madras, where in every part the means for the removal of drainage is imperfect, the worst drained areas usually coincide with those that have the densest population, but it is interesting to note that the death-rate follows drainage rather than either water-supply or density of population. The following table shows the death-rates of the different divisions, their density of population and the nature of their drainage and water-supply.

The diagram on Plate XXI facing this page shows graphically the death rate of the different divisions. It is inserted because it conveys the position at a glance better than the figures in the table.

Conclusion.

261. As a result of the considerations of the previous paragraphs it appears indubitable that drainage has a most important bearing on the health of Madras, and that in view of the present high death-rate, it is most important that a system for the efficient drainage of the city should be carried out with the least possible delay.

Table showing Death-rate in Madras City, 1906 to 1910, in relation to Drainage, Density of Population and Water-supply.

Name of Area.	Municipal Divisions.	Average Death-Rate Per 1,000, 1906—10. For Division.	Average Death-Rate Per 1,000, 1906—10. For Group.	Nature of Drainage.	Population per acre, 1911.	Nature of Water-supply.
Tondiarpet ...	1	48·6	50·2	Bad open drains.	50	Deficient.
	2	58·5			54	
	3	43·5			21	
Georgetown East ...	4	47·3	43·5	Good open drains.	115	Fair supply.
	5	37·0			148	
	6	44·5			160	
Georgetown West ...	7	48·6			159	
	8	43·0			230	
	9	46·7			148	
Perambur ...	10	37·2	...	...	36	
Purasawakum ...	11	37·8	37·2	Partially sewered but some very insanitary area.	91	Good supply.
Vepery ...	12	33·0			66	
Chintadripet ...	16	37·2			155	Fair supply.
North Triplicane ...	17	40·9			109	
Egmore ...	13	34·9	37·0	Mostly sewered.	42	Good supply.
South Triplicane ...	18	36·7			114	Fair.
South Mylapore ...	20	39·4			11	Deficient.
Kilpauk ...	14	34·2	33·4	Large compound, rural conditions; some paracherries.	10	Good supply.
Nungambakum ...	15	32·6			15	
North Mylapore ...	19	30·7	30·7	Wholly sewered.	22	Deficient.

Note.—Death-rates have been worked out on population of 1911 census.

CHAPTER XV.

SEWER GRADIENTS—VELOCITIES—SILT TRANSPORTATION.

262. Considerations affecting gradients. 263 Importance of adopting flattest gradients which can be used with safety. 264. Gradients limited by velocities which may be allowed. 265. Velocities required to keep solids in suspension. 266. Minimum velocity 1½ feet per second. 267. Maximum velocity varies with the conditions. 268. Experimental determination of sewage flow in Madras. 269. Variations in the rate of sewage flow. 270. Velocity should be 2·39 feet per second when flowing half full. 271. Gradients required to insure a velocity of 2·39 feet per second in sewers flowing half full. 272. Ordinary flattest gradients. 273. Comparison of gradients. 274. Gradients actually employed.

Experiments on flow of Sewage in Pipes.—275. Experiments on the flow of sewage in 6-inch and 9-inch pipes laid at the flattest gradients. 276. Experiments at Sewage Farm. 277. Curve showing velocities and discharges. 278. Materials experimented with. 279. Results obtained by experiment. 280 Quantitative results.

Considerations affecting gradients.

262. The question of the gradients at which the sewers should be laid is of vital importance in all sewerage schemes. It is especially important in schemes for cities like Madras, where the surface is so flat that very little assistance is to be obtained from the natural slope of the ground, and where a porous subsoil with water only a few feet from the ground surface makes deep sewer laying an impossibility.

Efficiency dictates gradients sufficiently steep to ensure that the system will perform its proper function—the removal of sewage—with a minimum amount of attention.

Economy requires that gradients shall be as flat as possible, in order that the cost of laying sewers at great depths, and the multiplication of pumping stations, may both be reduced to a minimum.

Importance of adopting flattest gradients which can be used with safety.

263. The great importance of choosing, for the main sewers, the flattest gradients which can be used with safety is well illustrated in the Tondiarpet Division of Madras.

With the gradients adopted for that district, *three* pumping stations only are required to drain South Tondiarpet.

If the gradients of the sewers had been made only slightly steeper, as follows :—

For	6	inches	diameter	pipes	from	1/135 to 1/100
,,	9	,,	,,	,,	,,	1/230 ,, 1/190
,,	12	,,	,,	,,	,,	1/340 ,, 1/295
,,	15	,,	,,	,,	,,	1/460 ,, 1/415
,,	18	,,	,,	,,	,,	1/580 ,, 1/540

it was found that *seven* pumping stations would be necessary to drain the same areas, assuming the depths of the pump wells to be the same in each case.

The initial cost of seven very small stations, in respect of land, buildings, engines, pumps, silt-pits, screening chambers—in fact everything—would be much greater than three stations of moderate size. It was found that, if the steeper gradients were used the initial cost would have been increased from Rs. 10½ lakhs to Rs. 14 lakhs, an increase of 33 per cent.

The cost of upkeep and of running the plant would also be very much greater for seven pumping stations than for three, in respect of everything :— wages, fuel, oil, repairs, renewals, depreciation, etc It was estimated that the cost of upkeep would be increased by 33 per cent.

Assuming that the same proportion would hold for the other sections of Madras,—and there is no reason to suppose it would not—then the initial cost of the drainage scheme for the whole city would be increased by 40 lakhs and the cost of upkeep by 2½ lakhs, including interest on capital cost.

This instance is sufficient to demonstrate, that it is of the utmost importance that the main sewers of Madras should be laid at the flattest gradients which are consistent with efficiency. It now remains to justify the belief that the gradients proposed will be efficient.

Gradients limited by velocities which may be allowed.

264. The gradient or slope of a sewer should be so determined that, under all the variations of flow, for which the sewer is designed, the velocity of the sewage shall lie between two limits :—

(*a*) *An upper limit of velocity*, beyond which there is danger of attrition of the sewer wall, and risk of the larger floating solids being left stranded owing to insufficient depth of sewage. In the sewage of Madras there is a considerable quantity of grit containing a large proportion of grains of quartz—the hardest of common minerals. To ensure that these quartz grains shall not erode the sewers, it is necessary to restrict the maximum allowable velocity to about 5 feet per second. This limit is not likely to be reached in Madras, except in the case of short branch sewers for which suitable arrangements have been provided.

(*b*) *A lower limit of velocity*, below which sand, silt and other materials, heavier than water, cease to be carried in suspension, and are deposited in the sewer. This velocity determines the flattest gradients which are permissible.

In the case of Madras the upper limit requires no further attention. The lower limit on account of its great importance will be considered in some detail.

Velocities required to keep solids in suspension

265. The following table will give an idea of the lowest mean velocities which are necessary to keep the heavier solids moving in a fairly smooth channel :—

Material.	Mean velocity in feet per second to keep it moving.
Fine clay	0·4
Sand size of aniseed	0·5
Gravel size of peas	0·8
Gravel size of beans...	1·6
Shingle about 1 inch in diameter ...	3·3
Angular stones 1½ inches diameter ...	4·5

Minimum velocity 1½ feet per second.

266. The figures in this table were experimentally determined by Du Buat. They show that a velocity of 1½ feet per second should be sufficient to transport any solid matter which may legitimately be introduced into the sewer: and experience with actual sewerage systems confirms this deduction from experiment.

It is on the basis that a velocity of at least 1½ feet per second shall be maintained with the ordinary minimum flow, that the proposed flattest gradients have been fixed.

Maximum velocity varies with the conditions.

267. It is the *minimum* flow which determines the flattest gradients which may be employed, because it is with the minimum flow that the velocity is least and the depth of sewage least, and these are the conditions most favourable for the deposit of materials carried in suspension.

Now the relation between the minimum flow and the maximum flow varies in different cities, because it depends largely on the amount of rainfall which is admitted into the sewers.

It is obvious that, if a sewer is designed to take all the rain-water which may fall on its drainage area during the monsoon, then the maximum flow will be very much greater than the minimum—in Madras it would be about 200 times as great—but the actual ratio will depend on density of population, permeability and steepness of ground, etc.

Even in England—where the rainfall is very much more evenly distributed than in Madras—the amount of rainfall admitted has a great effect on the relation of the maximum to minimum flow, and therefore on the gradients and sizes of the sewers.

To illustrate this point the table below has been prepared. It shows limiting gradients commonly adopted for flat towns in good English practice (and the resulting velocities when flowing half full) for sewers designed to deal with different quantities of rain-water—

Diameter of Sewer in inches.	Separate system admitting only sewage and rain-water from yards and roofs.	Combined System.	
		To carry off 6 times dry weather flow.	To carry off 12 times dry weather flow.
6	1 in 150	1 in 135	1 in 87
9	1 in 335	1 in 230	1 in 150
12	1 in 490	1 in 340	1 in 222
15	1 in 660	1 in 460	1 in 295
18	1 in 840	1 in 580	1 in 375
21	1 in 1,000	1 in 720	1 in 460
24	1 in 1,250	1 in 860	1 in 550
Velocity in feet per second when running half full.	2¼	2⅔	3⅓

From this table it will be seen how the limiting gradients and maximum velocities vary according to circumstances. In the scheme proposed in this report the amount of rain-water admitted will approximate to the first of the three sets of conditions given above. But there are other reasons, such as the presence of silt in the sewage and the absence of useful flushes from house connections, which render steeper gradients essential in Madras.

Experimental determination of sewage flow in Madras.

268. As it is the *maximum* flow which has always been referred to in previous reports, it will be convenient to continue to do so, and to find out what the velocity will be under the conditions of maximum flow in Madras sewers when the minimum rate of flow is $1\frac{1}{2}$ feet per second.

Variations in the rate of sewage flow.

269. In order to determine the variations in the rate of sewage flow, experiments were made at the Pumping Stations at Lang's Garden and Law College. The Lang's Garden Pumping Station area was chosen because it is the only area drained mainly by underground sewers where the pumps are capable of dealing with the dry weather flow and where there is an adequate water-supply. The Law College area was selected because at this station the pumps are able to deal with the flow which is mostly brought in by open drains. The levels of the sewage in the pump wells are kept constant and the quantities pumped were measured by means of the Venturi Meters which had previously been carefully calibrated. The results of the experiments are plotted as diagrams on Plate No. XXII. From these diagrams, the following figures are obtained for the two stations :—

	Law College Pumping Station.	Lang's Garden Pumping Station.
Mean Quantity pumped in gallons. per hour	31,800	12,200
Ordinary Minimum ,, ,, ...	23,000	7,000
Maximum ,, ,, ...	50,000	21,000
Ratio of Mean to Maximum	0·63	0·58
,, ,, Minimum	1·38	1·74
,, Maximum to Minimum	2·17	3·00

From these figures, it will be seen that the maximum dry weather flow is about twice the average, and the ordinary minimum about $\frac{3}{5}$ of the mean.

By the *ordinary minimum* is meant the quantity which should be treated as the minimum for sewage design. As will be seen from Plate No. XXII the *absolute minimum* occurs between midnight and 2 A.M., but during this time the liquid consists of practically clear water and does not affect the case.

The maximum dry weather flow may then be taken with safety to be twice the average, and the ordinary minimum to be one-half the average, and this gives a relation of maximum to minimum dry weather flow of 1 to $\frac{1}{4}$. This ratio has been adopted as a basis in the calculations which follow.

270. But the sewers in the scheme now submitted are designed to take the maximum dry weather flow *plus an allowance of one-third of that quantity for rain-water which cannot be excluded.* Therefore the ratio between the minimum and maximum flows becomes as one quarter is to one and a third (as $\frac{1}{4}$ is to $1\frac{1}{3}$) or as 3 is to 16.

Velocity should be 2·39 feet per second when flowing half full.

As all except the largest sewers are designed to take the maximum flow when running half full, the ordinary minimum flow will amount to $\frac{3}{32}$ of the carrying capacity of the sewer running full.

Now $\frac{3}{32}$ is carried when the depth of flow in the sewer is 0·207 of the diameter and when the velocity is 0·627 of the velocity of the same sewer flowing full; so that the gradients of the sewers should be such, that their maximum velocity when flowing half full is at least $\frac{1·5}{0·627} = 2·39$.

271. The gradients required to produce these velocities are as follows—

Gradients required to insure a velocity of 2·39 feet per second in sewers flowing half full.

Diameter of Pipe. / Gradient.	6 ins.	9 ins	12 ins.	15 ins.	18 ins.	21 ins.	24 ins.
	1 in 170	1 in 290	1 in 425	1 in 575	1 in 730	1 in 900	1 in 1075

These are absolutely the flattest gradients allowed in the scheme put forward, but they are used only for short lengths of sewers where necessary to avoid the multiplication of pumping stations and will be provided with ample flushing arrangements. They are exceptional and should not be regarded as the normally flattest gradients; any more than the minimum gradient for house drains is to be considered 1 in infinity just because, in an exceptional case, a hospital drain provided with ample flushing may be allowed to be laid dead flat

272. The ordinary flattest gradients used throughout the scheme put forward are:—

Ordinary flattest gradients

Diameter of Pipe. / Gradient.	6 ins.	9 ins.	12 ins.	15 ins.	18 ins.	21 ins.	24 ins.
	1 in 135	1 in 230	1 in 340	1 in 460	1 in 580	1 in 720	1 in 860

With these flattest gradients the velocities in the sewers with different flows will be—

With minimum dry weather flow ... 1·68 ft. per second.
With mean ,, ,, ,, ... 2·03 ,, ,, ,,
With maximum ,, ,, ,, ... 2·43 ,, ,, ,,
With maximum flow for which sewers are designed } 2·66 ,, ,, ,,
With flow $\frac{3}{4}$ depth of pipe ... 3·03 ,, ,, ,,

These gradients have been obtained from the tables prepared by Santo Crimp & Bruges. These tables are based on the results of experiments conducted on sewers, and are believed to be the best available: they have been used in England by most of the leading Civil Engineers and found reliable; and they agree closely with the Napier Park pipe experiments described below.

Their exceptional value lies in the fact that they have been constructed as the result of repeated experiments, conducted under conditions of ordinary working, on sewers of the sizes proposed for Madras. They are preferred to tables based on Kutter's formula, because this formula was derived from experiments carried out in channels, and is known to give velocities which are too low for pipes up to 18 inches in diameter.

An interesting confirmation of the sufficiency of a maximum dry weather flow velocity of $2\frac{1}{2}$ feet per second is afforded by the experiments on the cast-iron pumping main which are described in Chapter XVIII. It was found that the main in the course of years has silted up till the velocity of sewage is $2\frac{1}{2}$ feet per second when the pumps are pumping the maximum quantity. Now the cast-iron main runs level on the average—sometimes downhill and sometimes uphill. The velocity required to move silt in such a main where the action of gravity is a hindrance is greater than that in a sewer where the fall in the direction of flow causes gravity to assist the silt in its movement downhill. Thus a maximum dry weather flow velocity of $2\frac{1}{2}$ feet per second should be greater than the minimum required to keep a sewer free from deposit where silt is excluded as far as possible.

Comparison of gradients.

273 For purposes of comparison the following table has been prepared, in which are set out the flattest gradients for sewers :—

(1) As laid in Madras.

(2) As now laid in Bombay.

(3) As laid in Stockport (England).

(4) As recommended by Baldwin Latham in his book on "Sanitary Engineering" which is the outcome of a very extensive experience of sewerage works all over the world.

(5) As proposed in this Report.

It will be noted that the gradients now recommended are the steepest, whilst those of the sewers formerly laid in Madras are by far the flattest—

Diameter of Sewer in inches.	FLATTEST GRADIENTS FOR SEWERS.				
	As adopt in			As recommended by Baldwin Latham.	As proposed in this Report for the ordinary minimum.
	As formerly laid in Madras.	Bombay.	Stockport (England).		
	(1)	(2)	(3)	(4)	(5)
6	1 in 330	1 in 150	1 in 135	1 in 137	1 in 135
9	1 in 500	1 in 265	1 in 300	1 in 206	1 in 230
12	1 in 600	1 in 385	1 in 400	1 in 386	1 in 340
15	1 in 1000	...	1 in 500	1 in 482	1 in 460
18	1 in 1000	1 in 660	1 in 650	1 in 579	1 in 580
21	...	...	...	...	1 in 720
24	...	1 in 980	..	1 in 772	1 in 806

Gradients actually employed.

274. Wherever possible, steeper gradients will be employed in Madras, for, although the gradients proposed should be efficient, steeper gradients giving velocities of from 3 to 5 feet per second are more desirable. The following table indicates the extent to which the ordinary minimum gradients are varied from. It will be noted that 57 per cent. of the pipe sewers are laid at gradients steeper than the ordinary minimum proposed :—

Summary of Lengths and Gradients of Proposed New Pipe Sewers.

Sizes of Pipes and ordinary minimum gradients.		Lengths at ordinary minimum grade.	Lengths at steeper gradients than ordinary minimum.	Lengths at gradients flatter than ordinary minimum.	Total lengths of Pipes.
		Stoneware Pipe Sewers.			
Inches.		Feet.	Feet.	Feet.	Feet.
6	1 in 135	101,151	338,838	2,000	461,989
9	1 in 230	156,572	201,196	39,856	397,624
12	1 in 340	37,278	7,469	14,664	59,411
15	1 in 460	24,335	...	9,258	33,593
18	1 in 580	10,540	240	7,974	18,754
21	1 in 720	8,230	1,675	11,498	21,403
Total Stoneware Pipes.		338,106	569,418	85,250	992,774
		Cast-iron Pipe Sewers.			
24	860	4,330	...	1,980	6,310
27	1,000	1,280	...	1,520	2,800
30	1,150	970	2,030	1,160	4,160
36	1,450	..		3,880	3,880
Total Cast-iron Pipes.		6,580	2,030	8,540	17,150
Grand Totals ...		344,686	571,448	93,790	1,009,924

For details showing lengths of sewers of different sizes according to the gradients at which they are laid, *see* Appendix V.

There are a few cases where slightly flatter gradients than the ordinary minimum are proposed in order to deal with special circumstances. In no case, however, has the calculated velocity for the minimum flow been reduced below 1·5 feet per second which is about the lowest velocity which will efficiently transport silt and small stone along pipe sewers. One of these special cases is that of the Gravitation Main from Edward Elliott's Road Pumping Station to Ice House Road Pumping Station. A 21-inch pipe is proposed here at a gradient of 1 in 830, but as nearly all the sewage in this pipe will have already been

deprived of its silt at Edward Elliott's Road Pumping Station, the 21-inch pipe will be quite efficient at the gradient proposed, and it is quite unlikely that any silt will deposit in the pipe, as the flow will always be considerable.

Experiments on flow of Sewage in Pipes.

Experiments on the flow of sewage in 6-inch and 9-inch pipes laid at the flattest gradients.

275. So important is the question of gradients, that it was considered advisable to test the flow in actual experimental pipe lines laid at the flattest gradients proposed, and to ascertain the transporting power of water in respect of the actual silt which finds its way into the sewers of Madras.

The first series of experiments were carried out at Napier Park. Two lines of pipes, one 6 inches and the other 9 inches in diameter were laid parallel and straight and the length of each was the same—110 feet from inlet to outlet. Vertical junctions were laid at short intervals so that the interior of the pipes might be inspected closely. The 6-inch pipes were laid at a gradient of 1 in 135. The 9-inch pipes were laid at a gradient of 1 in 230

The liquid used was dirty water resembling sewage ; it was pumped into a circular feed tank, whence it gravitated to the pipes, passing first through a valve by which the quantity flowing was regulated, and then into a rectangular trough provided with a weir by which the quantity was measured. The outlet was connected with a pit from which the liquid was pumped back to the feed tank. In order to maintain a constant head, the overflow of the feed tank was kept just running.

The mean velocity was determined by introducing a solution of lime at the inlet end, and noting how long it took to reach the outlet, as measured by the average of the time taken before the lime first began to appear, and until the liquid became clear again. It was assumed that the slightly lower velocity at the inlet into the pipe and the slightly higher velocity at the outlet neutralized one another, so that the mean velocity was obtained by dividing the length of the pipe by the time taken to traverse it.

In the float experiments, teak shavings were used rolled into cylinders about an inch in diameter and an inch in depth. They floated practically wholly immersed.

Experiments on the velocity between points unaffected by the end effects proved that this assumption was correct within the limits of error of the observations.

The accuracy of the weir formula was checked by taking a positive measurement of the liquid flowing, as determined by the rate at which the tank was emptied. A reference to item No. 3 of the table will show that the agreement is remarkably close between the rate of flow as thus determined, and the rate as calculated by the weir formula.

A summary of the experiments is given in the following table. Each result is the average of a number of measurements. To record the individual observations, more space than is available would be required :—

Table showing summary of results of experiments on flow of sewage in 6-inch and 9-inch pipes laid at the ordinary minimum gradients proposed for Madras.

		6-INCH PIPES.				9-INCH PIPES.			
		Minimum flow.	Mean flow.	Maximum D. W. flow.	Half full.	Minimum flow.	Mean flow.	Maximum D. W. flow.	Half full.
1	Head above weir, 1 foot. long in inches	0·75	1·20	2·25	2·75	1·28	2·02	3·98	4·37
2	Flow from weir formula, in gallons, per minute	18·80	37·6	98·0	130·0	41·5	83·1	221·5	25·3
3	Flow, as measured by fall in level in circular tank, in gallons, per minute	18·90	...	...	...	42·7	...	...	...
4	Mean velocity in pipes as measured by lime solution, in feet, per second	1·73	2·25	3·00	3·16	1·72	2·11	2·82	3·06
5	Velocity from Tables of Santo Crimp & Bruges and for same quantity and gradient, in feet, per second	1·68	2·03	2·66	2·66	1·68	2·03	2·66	2·66
6	Velocity of floats, in feet, per second	2·08	2·56	3·44	3·67	2·12	2·50	3·38	3·66
7	Depth of stream, in inches ...	1·20	1·68	2·76	3·00	1·80	2·61	...	...
8	Width of stream surface, in inches.	$4\frac{3}{8}$	...	$5\frac{13}{16}$	$5\frac{15}{16}$	$7\frac{3}{16}$	$8\frac{1}{4}$	...	...
9	Length of pipe, experimented on, in feet	110	110	110	110	110	110	110	110
10	Gradient of pipes	1 in 135	1 in 135	1 in 135	1 in 135	1 in 230	1 in 230	1 in 230	1 in 230
11	Head of entry in inches ..	...	...	...	2·6	0·23	...	...	...

Experiments at Sewage Farm.

276. Experiments were also carried out on the flow of sewage through the 18-inch cement pipes which have been laid underground for irrigation purposes at the Sewage Farm.

The flow was measured by means of a weir placed across a manhole 200 feet upstream of the top end of the length experimented with. The length of sewer under observation was 600 feet. The following table gives an abstract of the results obtained :—

EXPERIMENT No. 1.

(1) Gradient	1 in 425	1 in 357	1 in 410	1 in 357
(2) Flow in cubic feet per minute	104	12 23	46·45	14·89
(3) Velocity in feet per minute	238	107	171	126
(4) Velocity per Santo Crimp's Tables	166	95	134	101
(5) Ratio $\frac{\text{No. 3}}{\text{No. 4}}$	1·43	1·12	1·28	1·25

These experiments confirm the conclusions already arrived at by the previous experiments that the velocities given in Santo Crimp's Tables are likely to be exceeded in ordinary practice. The high velocities are the more remarkable inasmuch as the pipes themselves were rough compared with glazed stoneware pipes and were not laid with the same care that would be used in sewer-laying.

Curve showing velocities and discharges.

277. Plate No. XXIII shows graphically, for 6-inch and 9-inch pipes, laid at the flattest proposed gradients, the velocities and discharges with different depths of sewage. The quantities can be read at a glance and it is probable that the diagrams will convey more information than many columns of figures.

The black lines are plotted from Santo Crimp's tables and the red lines represent the results of the experiments just described.

It will be seen that in every case the velocities and discharges as determined experimentally are slightly greater than those given by the Tables, so that by using these tables a factor of safety is secured.

Materials experimented with.

278. By means of the experiments described, were measured the velocities of the sewage in 6-inch and 9-inch pipes, laid at the flattest gradients proposed.

From the velocities obtained by the experiments described in the last section, and in the light of experience with sewers, there is little doubt that all the flows, experimented with, would be able to transport silt in moderate quantities.

It was, however, considered advisable to verify this conclusion by experimenting with silt actually deposited in Madras sewers.

The silt used was that which had choked up some concrete pipes in Mylapore: it consisted almost wholly of quartz sand, with a small proportion of organic matter. By sifting through wire screens, it was found to be of the following degrees of fineness: –

Material No. I, passing $\frac{1}{8}$-inch mesh	88%
Material No. II, rejected by $\frac{1}{8}$-inch mesh passed by $\frac{1}{4}$-inch mesh ...	8%
Material No. III, rejected by $\frac{1}{4}$-inch mesh passed by 1-inch mesh ...	3%
Material No. IV, rejected by 1-inch mesh	1%
	100%

In addition to the silt, pieces of granite road metal, fragments of brick, etc, were experimented with as described below.

Results obtained by experiment.

279. The following results were obtained with 6-inch and 9-inch pipes laid at gradients of 1 in 135 and 1 in 230, respectively. The arrangements were the same as for the experiments on the velocities of flow, described in the last section.

Half buckets of unsifted silt were introduced at several junctions: all the silt was *gradually* removed *by the minimum flow*. The finest material was carried away at once: the coarser particles were more gradually moved. The amount of the silt introduced at any one time, largely determined the period taken to carry it away—the greater the quantity of silt, the longer the time required.

Granite stones passing a $1\frac{1}{2}$-inch mesh and rejected by a 1-inch mesh and roughly cubical in shape, were moved along slowly, but were arrested by bad joints. Flat stones were not moved by the minimum flow, but were all flushed out by the maximum flow. With the mean flow a granite stone $2\frac{3}{4}$ by $2\frac{1}{4}$ by $1\frac{1}{2}$ inches with rounded edges passed all bad joints readily and moved all stones which had been arrested previously by the joints.

These experiments emphasize the great importance of laying all sewers true to line and level, and the evil consequences which follow bad laying and

jointing. They also show that the shape of the material has a considerable influence in determining whether it shall be carried along or not. And further that *the quantity of silt which can be transported per gallon of sewage flowing at a given velocity, is strictly limited.*

280. The following were the velocities of silt and stones as measured :— **Quantitative results.**

Flow in gallons per Minute.	Nature of Material.	Velocity of Material in feet per second.	Mean Velocity of clear liquid.
6-inch pipes.			
18·4 (minimum)	Silt Material No. I	1·62	1·73
36·8 (mean)	Silt Material No. I	2·20	2·25
Half Full	Piece of flat brick	1·67	3·16
Half Full	Stone, 2″ × 2″ × 2″	2·12	3·16
Half Full	Brick, 4″ × 3″ × 2″	2·04	3·16
Half Full	Palmyra fruit (floating)	3·7	3·76
9-inch pipes.			
41·5 (minimum)	Silt Material No. I	1·63	1·72
41·5 (minimum)	Silt Material No. II	1·47	1·72
4·15 (minimum)	Silt Material No. III	1·25	1·72

As a result of the above investigations, the writer is confirmed in his opinion that the gradients proposed are suitable, provided :—

(1) That improper materials, including an excessive amount of silt, be excluded from the sewers. The means of doing this are described in the section dealing with connections to sewers.

(2) That the heads of sewers and other special points be adequately flushed. (Dealt with under "Flushing" paragraphs 193 to 198).

(3) That reasonable supervision be exercised.

CHAPTER XVI.

SEWER CLEANING AND SILT-CATCHERS.

281. Experiment to ascertain cleaning required with existing sewers. 282. Experiment to determine nature of silt passing through silt catchers. 283. Experiment determine frequency with which silt catchers have to be emptied.

281. Experiments have been carried out to ascertain what amount of sewer cleaning would be necessary to keep the existing sewers (which are laid at gradients too flat to give self-cleansing velocities under ordinary conditions of flow) clean and in working order under the following conditions :—

Experiment to ascertain cleaning required with existing sewers.

(1) Without means for excluding silt being provided.

(2) With silt catcher buckets on house connection.

The sewers experimented with were those in Naval Hospital Road, Thiruvengada Moodely Street and Cuddapah Rungiah Chetty Street. These sewers discharge into the pipe sewer in Poonamallee High Road. They were chosen because it was thought that it would be possible to work the Periamet pumps so as to prevent the sewers becoming surcharged. As a matter of fact it was found impossible to prevent surcharging.

The experiments were commenced in July 1911 and are still being continued. Duration, up to present, 21 months. The sewers were cleaned by drawing a ball of spun yarn through the sewer and the silt was measured wet in buckets. The ball did not take out all the silt and leave the sewer absolutely clean, but it was assumed that it *left the same amount in the sewer* after each cleaning, and that the amount taken out was what had collected in the sewer since the previous cleaning.

Size of pipe 6 inches dia.	Gradients from 1 in 240 to 1 in 360	Total length of sewer cleaned in feet.	
		C. ft. of silt collected per foot of sewer per month.	
		In sewer.	In silt-catcher.
Without exclusion of Silt	1st cleaning to 2nd cleaning.	0·027	...
	2nd ,, 3rd ,,	0·0065	...
	3rd ,, 4th ,,	0·0057	...
	4th ,, 5th rain.	0·0096	...
	5th ,, 6th ,,	0·0055	...
With Silt-catchers.	6th cleaning to 7th cleaning.	0·0056	0·050
	7th ,, 8th ,,	0·0052	
	8th ,, 9th rain.	0·0062	
	9th ,, 10th ,,	0·0023	
	10th ,, 11th ,,	0·0022	

These are the actual results of the experiments, but in the case of the experiments with silt-catchers, it is only the last two readings that should be taken,

as until then the conditions had not become normal. From an accurate knowledge of all the circumstances, it is concluded that the silt collected per foot of these sewers per month may be taken 0·0062 cubic foot without silt catchers and 0·0022 cubic foot with silt-catchers.

If the average rate of accumulation of silt in the sewer be taken as 0·0062 cubic foot per foot of sewer per month without silt-catchers this would mean that the sewer would silt up to a depth of fully $\frac{3}{5}$ inch in one month if it were clean to start with. If 0·0022 cubic foot per foot of sewer per month be taken as rate of silting up with silt-catchers, the sewers would silt up to a depth of something less than $\frac{1}{4}$ inch in one month.

The experiment, so far as it goes, shews that the provision of silt-catcher buckets has reduced the amount of silt taken out of the sewers to $\frac{1}{3}$ of the amount which was taken out before silt-catcher buckets were provided. But the benefit is in reality much greater because the silt that does pass through is so fine that most of it would, with efficient pumping, readily be carried to the stations, through the pumps and up to the Farm. The sewers experimented with—in common with all the sewers of Madras—are subjected to daily backing up. Hence a great proportion of material even so fine as that passing the silt-catchers is deposited in the sewers. This will not occur to nearly the same extent when adequate pumping plant has been installed.

Experiment to determine nature of silt passing through silt-catchers.

282. As the first three cleanings after the introduction of silt-catchers did not shew the expected reduction in amount of silt taken from sewers, an experiment was made to ascertain how much, if any, silt passed through the silt-catcher buckets into the sewer. Three buckets were arranged in series on one house connection (experiment made on two different house connections), the sewage having to pass through all three buckets before finding its way into the sewer. The buckets were allowed to remain without cleaning until the first bucket became full of silt. The three buckets were then taken out and the quantity of silt in each measured after having been dried.

No. 1 contained 373 cubic inches (averages °/₀ of experiments).
„ 2 „ 171 „ „ „
„ 3 „ 55 „ „ „

It was noticed that in buckets 2 and 3 the silt collected, which would otherwise have gone into the sewer, was of a very fine, light and almost floculent nature and would very probably have been easily carried off by even a very small flow. An experiment was therefore made to ascertain how much of the contents of buckets 2 and 3 (which in ordinary circumstances would have passed into the sewer) would remain in the sewer and not be carried off at the low velocities obtaining in the sewer. The silt was placed in water having a velocity of less than $\frac{1}{2}$ foot per second and the heavier silt which remained again measured.

From No. 1 bucket remained 239 cub. ins. Amount passed off in flow 36 °/₀
„ „ 2 „ „ 29 „ „ „ „ „ 83 °/₀
„ „ 3 „ „ 6 „ „ „ „ „ 89 °/₀

so that the first bucket caught practically all the heavy silt; the amount of heavy silt which passed through being only $1\frac{1}{4}$ °/₀ of the total amount. In other words $98\frac{3}{4}$ °/₀ of the heavy silt was caught in the first bucket.

In the sewer cleaning experiments it was found after fitting silt-catchers that 0·05 cubic foot of silt per foot of sewer per month was caught in the silt buckets and 0·0022 cubic foot per foot per month was taken out of the sewer which is about 3·8 °/₀ of the total silt This checks fairly well with the silt-catcher bucket experiment which shews that about 1¼ °/₀ of the total silt finds its way into the sewer even under the best conditions. The emptying and cleaning of the silt buckets was carried out by ordinary coolies who did their work with the usual amount of carelessness. This carelessness took the form of emptying some of the heavy silt into the siphon trap, and this is sufficient to account for the increased amount taken out of the sewer.

This experiment proves that the silt-catcher fulfils its function of catching practically all the heavy silt which—even with efficient pumping—would be deposited in the existing sewers.

Experiment to determine frequency with which silt-catchers have to be emptied.

283. Experiments were also made to ascertain how often silt-catcher buckets fitted to house connections require to be emptied. House connections in the following three streets in Periamet were fitted with silt-catcher buckets :—

(1) Naval Hospital Road.
(2) Thiruvengada Moodely Street. } 77 silt buckets.
(3) Cuddapah Rungiah Chetty Street.

These streets were selected as being fairly typical of the majority of streets in Madras.

The buckets were inspected every day and any bucket was emptied when it was seen that it could not be allowed to remain for another day without becoming too full to do its work properly.

The following table shows how often the buckets required to be emptied :—

Number of days which elapsed before bucket required to be emptied.	Number of buckets which required to be cleaned after time stated.
1 day	One bucket required to be cleaned practically every day, but the circumstances were quite exceptional, 10 families, total 52 people in house.
2 days	5
3 „	5
4 „	7
5 „	4
6 „	7
7 „	7
8 „	9
9 „	13
11 „	1
13 „	11
14 „	4
18 „	1
19 „	2
over 19 „	Total No. of house connections. 77

It will be seen that with the exception of one case, which is quite abnormal, one cleaning every three days would keep the silt-catcher buckets working properly. If the open sullage drains are curbed as required by the byelaws proposed in Chapter XXI one cleaning a week should suffice. At present the

traps on house connections, which are not fitted with silt-catcher buckets, have to be cleaned out every day. The provision of silt-catcher buckets, and curbing the open drains, will, therefore, reduce the amount of cleaning required, and correspondingly, the staff of cleaning coolies, to one-seventh of what is required at present. As already pointed out the silt-catcher buckets also very much reduce the amount of silt which finds its way into the sewers and consequently greatly reduce the amount of sewer cleaning required.

In order to ascertain if there was any relationship between the amount of silt collected and the number of people draining to the silt bucket, the information shewn on the following table was obtained :—

Number of families in the house.	Number of houses having stated number of families.	Average number of persons per family.	Average number of persons per house, *i.e.*, draining to silt bucket.	Average number of days elapsing before required to empty silt bucket.
1	22	6	6	12
2	9	$4\frac{1}{4}$	$8\frac{1}{2}$	10
3	8	$3\frac{2}{3}$	11	9
4	9	4	16	$6\frac{1}{2}$
5	4	$3\frac{1}{2}$	$17\frac{1}{2}$	6
6	7	$3\frac{1}{4}$	$19\frac{1}{2}$	$5\frac{1}{2}$
7	3	4	28	$6\frac{1}{2}$
8	2	3	24	$6\frac{1}{2}$
9	2	4	36	7
10	1	$5\frac{1}{4}$	52	Practically daily cleaning.

50 of the courtyards were paved and 27 not paved The drains are not curbed. Whether courtyards were paved or not appeared to have little effect in these particular experiments, though it is certain that a drain from an unpaved yard with a loose surface would carry to the sewer much more silt than a clean paved yard. Most of the houses had at least one water tap, some having two, three or four taps.

CHAPTER XVII

EXISTING SEWAGE PUMPING PLANT.

284. Existing Pumping Stations. 285. Engine and Pump Tests.

Mylapore Pumping Station.—286. Description of Plant. No. 1 Engine and Pump. No. 2 Engine. Cost of Pumping.

Ice House Road Pumping Station.—287. Description of Plant. No. 1 Engine and Pump. No. 2 Engine and Pump. Cost of Pumping (taken over one month).

Lang's Garden Pumping Station.—288. Description of Plant. No. 1 Engine. No. 2 Engine. Cost of Pumping (taken over one month).

DeMellow's Road Pumping Station.—289. Description of Plant. No. 1 Engine and Pump. No. 2 Engine and Pump. Cost of Pumping.

Vepery Pumping Station (temporary)—290. Description of Plant.

Napier Park Pumping Station—291. Description of Plant. Cost of Pumping.

Law College Pumping Station—292. Description of Plant. Cost of Pumping.

Rayapuram Pumping Station—293. Description of Plant. Cost of Pumping.

294. Summary of cost of pumping. 295. Remarks on tests. 296. Economy effected by new pumping plant.

284. Excluding the three pumping stations now in course of construction in Tondiarpet, there are eight sewage pumping stations in Madras. Some particulars of the pumping machinery are given in the following table :— **Existing Pumping Stations.**

Name of Station.	Number of Units.	Source of motive power.	Horse power of each engine.	Maker and Type of Engines.		Maker and Type of Pumps.
			Engines.			*Pumps.*
Mylapore ...	2	Oil	30	Hornsby.	4-cycle.	Gwynne's Centrifugal.
Ice House Road ...	2	Steam	...	Gwynne.	Simple non-condensing.	Do.
Napier Park ...	2	Steam	...	Worthington.	Compound direct acting, non-condensing.	Worthington's direct acting.
Lang's Gardens ...	2	Steam	...	Do.	Do.	Do.
DeMellow's Road...	2	Oil	40	Hornsby.	4-cycle.	Gwynne's Centrifugal.
Vepery* ...	1	Oil	40	Do.	Do.	Do.
Law College ...	3	Steam	...	Worthington.	Triple compound direct acting, surface condensing.	Worthington direct acting, non-rotative.
Rayapuram ...	2	Steam	...	2 Worthington. 1 Gwynne	2 Triple compound direct acting, surface condensing, 1 simple non-condensing.	Worthington's direct acting, non-rotative.

* Vepery is a temporary station. It has been installed to assist DeMellow's Road which was quite incapable of dealing with the sewage coming to it. It will be dispensed with as soon as the plant proposed for the Purasawakkum Station has been installed.

The recently installed pumps at the Law College and Rayapuram stations are able to deal satisfactorily with all the sewage which comes to them. These two stations deal with the sewage brought to them by the open drains of Georgetown.

The six remaining stations pump all the sewage from the Madras sewers plus a considerable quantity collected in open drains.

With the exception of Mylapore, all the stations are underpowered and the pumps are unable to deal with the maximum quantity of sewage that comes to them. The consequence is that every day the sewers of Madras are very nearly all of them surcharged, the flow becomes very slow, silt is freely deposited, ventilation ceases, and foul gases escape not only through the numerous untrapped connections, but also through the traps owing to the compression of the gas in the connections by the rising sewage.

Engine and pump test.

285. When, in the year 1909, the pumping plants were placed in charge of the writer, he immediately set to work to ascertain what the pumps were doing. It was impossible at that time to determine with sufficient accuracy the quantity pumped, for, with the two types of pumps in use, namely, the direct-acting Worthington and the belt-driven Centrifugal, it is very difficult to estimate the quantity without meters. In the case of the Worthington pump, the length of stroke is not constant and is frequently short while the slip past the pump plungers is a difficult quantity to determine. With Centrifugal pumps, it is quite impossible to estimate the delivery accurately unless there is some method of measuring the discharge. In fact, with some of the Centrifugal pumps in Madras, the writer has found that at times there is no discharge at all, the pump merely churning the sewage without driving it forward.

In these circumstances, Corporation sanction was obtained to furnish every station with Venturi meters, Pump Pressure and Sewage Level Recorders. These Meters and Pressure Recorders have now been installed and the results have been continually recorded during the last twelve months. Careful experiments were made to calibrate accurately the meters and pressure gauges.

Experiments have been made to determine the indicated and brake horse powers of the engines. The results of the tests at each station are given separately in the following paragraphs. The new stations at Law College and Rayapuram have been tested as well as the existing stations. In all cases, the figures were obtained under normal working conditions and no special preparations were made.

Before the tests could be carried out, suitable brakes had to be made; suitable levers for actuating the indicators had to be manufactured and many arrangements requiring much thought and patience had to be carried through.

The Indicated Horse powers were determined with a McInnes Dobbie Indicator.

The Brake Horse powers with a two strand rope brake with spring balances for varying the load.

The Pump Horse power was from the rate of pumping, the pressure and suction heads as registered respectively on the diagrams of the Venturi Meter, pump pressure and suction lift recorders.

The engines and pumps were run at as many different speeds as possible both above and below the nominal working speeds. The duration of each test was about 2 hours.

The powers and efficiencies of the pumping plants were obtained from experiments especially carried out for the purpose.

The costs were obtained from the daily returns of ordinary working for considerable periods.

The periods chosen were anterior to the power tests, thus rendering it certain that no special efforts to obtain economical running could be obtained.

MYLAPORE PUMPING STATION.

Engine and Pump Tests.

Description of Plant.

286. *Engines.*—Two Hornsby-Ackroyd Oil Engines marked 32 B. H. P. Stroke 19 inches, diameter of piston 16 inches, diameter of flywheel 73 inches, diameter driving pulley 44 inches.

Pumps.—5-inch Gwynne's Centrifugal, diameter of pulley 10 inches, belt drive.

The flow of sewage to the pumps is small and one engine and pump, working for about 10 hours out of the 24, is capable of dealing with the flow. The engines and pumps are used alternately changing over about every month or so.

The vaporisers and combustion chambers have, as a rule, to be cleaned out every shift of 8 hours, sometimes more often.

No. 1 Engine

No. 1 *Engine and Pump* (left hand on entering station).

The tests were made at pumping rates varying from 11,000 gallons per hour to 20,000 gallons per hour against a pressure of about 51 feet of head with a suction lift of about 10 feet.

Engine speed in revolutious per minute	...	180 to 200.
Indicated H. P. at different loads varied from	...	27 ,, 40.
Brake H. P. ,, ,, ,,	...	8 ,, 20.
Pump H. P. ,, ,, ,,	...	2 ,, 6.
Engine efficiency at different loads varied from	...	30% to 50%.
Pump ,, ,, ,, ,,	...	25% ,, 33%.
Combined engine and pump at different loads varied from		7·5% ,, 15%.

About 20 I. H. P. was required to drive engine only with no load at 200 revolutions per minute.

At engine speed of 200 revolutions per minute, pump speed should be 885 revolutions per minute if no slip.

Actual pump speed was 830 revolutions per minute which shows a belt slip of 6·2%. New belt gave only $2\frac{1}{2}$% slip. During test the engine showed signs of carbonising in combustion chamber, due to excess of oil, governor not acting properly, this probably reduced the efficiency a little.

No. 2 Engine.

No. 2 Engine (right hand on entering station).

Tests made at pumping rates varying from 17,000 gallons per hour to 30,000 gallons per hour against a pressure of about 60 feet of head with about 10 feet to 10 feet 6 inches of suction lift.

Engine speed in revolutions per minute	...	184 to 200.
Indicated H. P. at different loads varied from	...	32 ,, 40.
Brake H. P. ,, ,, ,,	...	17 ,, 22·5.
Pump H. P. ,, ,, ,,	...	6 ,, 10·5.
Engine efficiency at different loads varied from	...	53% to 56%.
Pump ,, ,, ,, ,,	...	35% ,, 47%.

Combined engine and pump at different loads varied from 19% to 26%.

About 18 I. H. P. was required to drive engine only with no load at 200 revolutions per minute.

Belt slip was about 6%.

Both No. 1 and No. 2 Engine and Pump appear to be in about the same condition.

Cost of Pumping.

The costs of pumping were taken over one month in ordinary dry weather. The work done was computed hourly from the venturi meter and pressure and suction recorder diagrams, the recorders having been previously tested and adjusted.

Average suction lift 10 feet 6 inches. Average pressure head 41 feet. Average rate of pumping 14,300 gallons per hour working 10 hours per day with one engine and pump.

Item.	Per Pump H. P. hour.	Per B. H. P. hour.	Per I. H. P. hour.	Per million gallons raised one foot.	Average Total Daily Cost.		
	ANNAS.	ANNAS.	ANNAS.	ANNAS.	RS.	A.	P.
Liquid fuel at 2·5 annas per gallon.	1·66	0·50	0·25	8·58	3	11	8
Stores—oil, waste, etc.... ...	0·58	0·17	0·08	3·08	1	5	6
Wages—driving staff, cleaners, etc.	2·66	0·83	0·41	13·83	6	0	5
Repairs and replacements ...	2·41	0·75	0·38	12·33	5	6	5
Supervision and office staff ...	0·57	0·16	0·08	2·83	1	4	0
Depreciation of machinery at 15%.	1·16	0·33	0·17	6·16	2	11	0
Total ...	9·04	2·74	1·37	46·81	20	7	0
Add for depreciation of buildings at 10% of cost ...	0·53	0·16	0·08	2·72	1	3	0
Total cost of pu... ... charges).	9·57	2·90	1·45	49·53	21	10	0

The cost of pumping at this station is made to appear too high compared with other stations, because owing to the small quantity of sewage, and pumps only work 10 hours per day as against 22 hours at the other stations, so that depreciation and staff charges are practically doubled

ICE HOUSE ROAD PUMPING STATION.

287. *Engines.*—2 No. Gwynne's Horizontal Single Cylinder Steam Engines. No condensers or economisers No governor. Diameter of cylinder $14\frac{1}{16}$ ins. Stroke 24 inches, diameter of flywheel pulley 9 feet. **Description of Plant.**

Pumps.—2 No. Gwynne's 6-inch Centrifugal Pumps, diameter of pump pulley $9\frac{9}{8}$ inches.

Tests made at pumping rates varying from 22,000 gallons per hour to 33,000 gallons per hour against a pressure head of from 47 feet to 60 feet with a suction lift of about 19 feet. **No. 1 Engine and Pump.**

No actual B. H. P. tests were made, but B. H P. was computed from "no load" indicator diagrams.

Engine speed in revolutions per minute	... ...	88 to 96.
Indicated H. P. varied from	... ...	33·6 „ 46·4.
Brake H. P. „ „	... ...	27·4 „ 37·0.
Pump H. P. „ „	... ...	7·2 „ 12·8.
Engine efficiency varied from	... ..	78% „ 80%.
Pump „ „ „	... ...	26% „ 32%.
Combined „ „ „	... ...	21·5% „ 25·5%.
Belt slip, engine speed 88 revolutions per minute, pump speed 960 revolutions per minute.		about 5·4%.

Both engine and pump appeared to be in fairly good order and the indicator diagrams show that the valves are fairly correctly set, requiring only a very slight adjustment.

About 8 I. H. P was required to run engine only at 96 revolutions per minute with no load.

Engine and pump were run at pumping rates varying from 18,000 gallons per hour to 31,000 gallons per hour against a pressure head of from 40 feet to 50 feet with a suction lift of about 18 feet 6 inches. **No. 2 Engine and Pump.**

Engine speed in revolutions per minute	... ...	80 to 88
Indicated H. P. varied from	... ...	32·2 to 51·0.
Brake H. P. „ „	... ...	26·0 „ 43·0.
Pump H. P. „ „	... ...	5·4 „ 11·0.
Engine efficiency varied from	... ...	81% „ 86%.
Pump „ „ „	... ...	20·7% „ 25%.
Combined „ „ „	... ...	17% „ 21·5%
Belt slip about	.. ..	5·5%.

Cost of Pumping (taken over one month)

Conditions during Test.—Ordinary dry weather. Average suction lift 18 feet. Average pressure head 36·5 feet. Average rate of pumping 37,000 gallons per hour working 24 hours per day.

Item.	Per Pump P. H. hour.	Per B. H. P. hour.	Per I. H. P. hour.	Per million gallons raised one foot.	Average daily cost.		
	ANNAS.	ANNAS.	ANNAS.	ANNAS.	RS.	A.	P.
Fuel, coal at Rs. 15-2-0 average per ton	2·71	0·70	0·58	13·70	40	11	10
Stores—oil, waste, etc ...	0·31	0·03	0·03	0·64	1	14	4
Wages—driving staff, firemen, etc.	0·47	0·12	0·10	2·35	6	15	9
Repairs and replacements ...	0·78	0·20	0·17	3·94	11	11	4
Supervision and office staff ...	0·10	0·03	0·02	0·49	1	7	4
Depreciation of machinery ...	0·22	0·05	0·04	1·09	3	4	0
Total ...	4·59	1·13	0·94	22·21	64	0	7
Add for depreciation of buildings ...	0·08	0·02	0·01	0·42	1	4	0
Total cost of pumping (all charges).	4·67	1·15	0·95	22·63	65	4	7

LANG'S GARDEN PUMPING STATION.

Description of plant

288. Two Worthington Compound Direct Acting Non-rotative Steam Pumping Engines.

No. 1. Engine

Diameter of cylinders high pressure 10 $\frac{1}{16}$ inches
" " low " 16 $\frac{1}{16}$ "
" " pump " 13 $\frac{7}{8}$ "
} Stroke 10 inches

Cylinders recently rebored and engine and pump generally overhauled.

Engine run, pumping about 26,000 gallons per hour, at 42 strokes per minute, against a head of about 73 feet and with about 12 feet of suction.

Boiler pressure, per square inch	in lbs.	about 100
Indicated H. P....	"	29·0
Pump H. P.	"	12
Efficiency of engine and pump combined ..	"	41·5%.
Pump slip	"	42 %.

Indicator cards show that there is some leakage past both valves and pistons. One engine and pump is usually capable of dealing with daily flow of sewage. (At 26,000 gallons per hour, 69 cubic feet per minute, in 10-inch diameter pumping main the hydraulic gradient would be about 1 in 430 and velocity 2·1 feet per second, if main were clean and unobstructed. This agrees fairly well with results got from hydraulic gradient tests on 19th October, 1912, and with pressures obtained in this test).

No. 2. Engine

Same type of engine and pump as No. 1.

Diameter of cylinders, high pressure, 10 inches
" " low " 15 "
" " pump " 13 "
} Stroke 10 inches

Engine was run at pumping rate of about 24,000 gallons per hour at 42 strokes per minute against a head of about 64 feet and with about 13 feet of suction.

Boiler pressure per square inch	in lbs.	about 90
Indicated H. P.	,,	21·75.
Pump H. P.	,,	8·25,
Efficiency	,,	38%
Pump slip	,,	51%

The remarks regarding valve setting and leakage for No. 1 Engine also apply to No. 2 Engine. In both engines the reduction between boiler pressure and initial pressure in H.P. cylinder is great. This is due to throttling down at the stop valve which is necessary as steam cylinders are too big in proportion to pump cylinder for the pressure against which pump has to work. A larger pump cylinder would probably show better results. In the meantime experiments will be made if any economy can be obtained by keeping the boiler pressure lower.

Conditions during Test.—Ordinary dry weather. Average suction lift 15½ feet. Average pressure head 37½ feet. Average rate of pumping 15,500 gallons per hour working 21 hours per day.

Cost of pumping (taken over one month).

Item.	Per Pump H. P. hour	Per I. H. P. hour.	Per million gallons raised one foot	Average daily cost.		
	ANNAS.	ANNAS.	ANNAS.	RS.	A.	P.
Coal at Rs. 15-2-0 average per ton ...	4·38	1·66	22 32	25	13	5
Stores—oil, waste, etc.	0·17	0·06	0 84	0	15	7
Wages—driving staff, stokers, cleaners, etc. ...	1·90	0·72	9 68	11	3	4
Repairs and replacements	1·28	0·49	6·54	7	9	2
Supervision and office expenses	0·21	0·08	1·08	1	4	0
Depreciation of machinery at 13% ...	0·51	0·19	2·57	3	0	0
Total ...	8·45	3 20	43·03	49	13	6
Add for depreciation of buildings at 5% ...	0·17	0·06	·86	1	0	0
Total cost of pumping (all charges) ...	8·62	3·26	43·89	50	13	6

DE MELLOW'S ROAD PUMPING STATION.

Description of plant.

289. *Engines.*—Two Hornsby-Ackroyd Oil Engines marked 40 B. H. P. Stroke 22½ inches, diameter of piston 16¾ inches, diameter of flyweeel 7 feet, diameter of belt pulley 44 inches.

Pumps.—8-inch Tangye's Centrifugal, diameter of pulley 10 inches.

No. 1 Engine and Pump.

No. 1 Engine and Pump (left hand on entering station).

The tests were made at pumping rates varying from 11,000 gallons per hour to 22,000 gallons per hour against a pressure of about 30 feet of head and with a suction lift of about 5½ feet

Engine speed in revolutions per minute ...	152 to 180
Indicated H. P. at different loads varied from ...	29 to about 36·5
Brake H. P. „ „ „ „ ...	12 „ 19
Pump H. P. „ „ „ „ ...	2 „ 5
Engine efficiency at different loads varied from ...	41% to 52%
Pump „ „ „ „ „ „ ...	17% „ 26%
Combined engine and pump efficiency at different loads varied from	7% to 14%

About 22 I. H. P. was required to drive engine only, at 200 revolutions per minute with no load.

Belt slip was nearly 11%.

No. 2 Engine and Pump.

The tests were made at pumping rates varying from 14,000 gallons per hour to 42,000 gallons per hour against a pressure of about 33 feet of head with a suction of about 4 feet 6 inches.

Engine speed in revolutions per minute	160 to 192
1 H. P. at different loads varied from	30 „ 45
B. H. P. „ „ „ „	12 „ 31
Pump H. P. „ „ „ „	3 „ 7·5
Engine efficiency at different loads varied from ...	40% to 69%
Pump „ „ „ „ „ „ ...	24% „ 26%
Combined engine and pump efficiency at different loads varied from ...	10% „ 17%

Belt slip was about 7%.

About 20 I. H. P. was required to drive engine only with no load. Vaporiser and combustion chamber joints leaking slightly. Gas leaking past piston in No. 1 engine and both engines are knocking slightly at heavier loads. Oil pumps and governor mechanism in both engines require overhauling and adjustment, as both engines carbonise badly. In fact both engines require complete overhauling. The engines do not appear to be capable of driving the pumps at required speed.

Cost of Pumping.

Conditions during Test.—Ordinary dry weather. Average suction lift 16 feet 6 inches. Average pressure head 41 feet 6 inches. Average rate of pumping 33,800 gallons per hour working 24 hours per day.

Item.	Per pump H. P. hour.	Per B. H. P. hour.	Per I. H. P. hour.	Per million gallons raised one foot.	Average daily cost.		
	ANNAS.	ANNAS.	ANNAS.	ANNAS.	RS.	A.	P.
Liquid fuel at 2·75 annas per gallon.	1·15	0·35	0·17	7·66	16	8	10
Stores—oil, waste, etc. ...	0·28	0·06	0·03	1·40	3	0	4
Wages--driving staff, cleaners, etc.	0·73	0·16	0·08	3·72	8	0	7
Repairs and replacements ...	1·74	0·40	0·20	8·87	19	2	10
Supervision and office staff, etc. ...	0·11	0·02	0·01	0·58	1	4	0
Depreciation of machinery at 15%.	0·52	0·12	0·06	2·68	4	2	0
Total ...	4·53	1·11	0·55	24·91	52	2	7
Add for depreciation of buildings at 10% of cost	0·11	0·02	0·01	0·55	1	3	0
Total cost of pumping (all charges).	4·64	1·13	0·56	25·46	53	5	7

VEPERY PUMPING STATION (TEMPORARY).

Description of Plant.

290. This is only a temporary station to relieve DeMellow's Road station. It is furnished with one engine and one pump. Same type and size of engine as at DeMellow's Road Pumping Station, but driving pulley 5 feet diameter. No pump test was made as pump casing was broken on day of test, and there was no time to test new pump.

Pump is 6-inch Gwynne's Centrifugal, with 10 inches diameter pulley.

Engine speed in revolutions per minute .. ... 168 to 200

Indicated H. P. at different loads varied from ... 35 „ 42·5.

Brake H. P. „ „ „ ... ... 13 „ 24.

Efficiency of engine at different loads varied from 37% to 56%. About 20 I. H. P. required to drive engine only with no load.

Belt slip about 6%.

There is no meter on the discharge from the pump, so that the quantities cannot be accurately measured. There will not be any great error if it is assumed that the results are similar to those obtained for the similar plant at DeMellow's Road Pumping Station.

NAPIER PARK PUMPING STATION.

Description of Plant.

291. *Engines.*—Two Worthington Compound Non-condensing Direct Coupled Steam Pumping Engines each capable of pumping 1,000 gallons of sewage per minute.

Diameter of high pressure cylinders	9″
„ low „	14″
„ pump plunger	15″
Length of stroke	15″
Diameter of suction pipe	14″
„ discharge	13″
„ main discharge	18″

Two Babcock and Wilcox Water-tube Boilers. Working pressure of 120 lbs. per square inch.

Cost of Pumping for one month.

Item.	29 days.			Cost per pump H P. hour.	Cost per mill. galls. raised 1 ft.	Average daily cost.		
	RS.	A.	P.	ANNAS.	ANNAS.	RS.	A.	P.
Coal at Rs. 15-2-0 average per ton ...	1,047	1	0	3·22	16·17	36	1	8
Stores—oil, waste, etc.	43	9	10	0·13	0·67	1	8	1
Wages—driving staff, firemen, etc. ...	288	12	8	0·88	4·46	9	15	4
Repairs and replacements ...	366	11	8	1·13	5·66	12	10	4
Supervision and office staff ...	36	4	0	0·11	0·56	1	4	0
Depreciation of machinery at 15% ...	195	12	0	0·60	3·02	6	12	0
Total ...	1,978	3	2	6·07	30·54	68	3	5
Add for depreciation of buildings, 5%...	43	8	0	0·13	0·67	1	8	0
Total cost all charges ...	2,021	11	2	6·20	31·21	69	11	5

Mean rate of pumping 35,000 gallons per hour, 25 feet head, 15 feet inches suction.

LAW COLLEGE PUMPING STATION.

Description of Plant.

292. Three Worthington Triple Expansion Surface Condensing Direct Coupled Steam Pumping Engines, each capable of pumping 870 gallons of sewage per minute against a total maximum head, including friction, of 70 feet.

Diameter of high pressure cylinder	6″
,, intermediate ,, ...	9″
,, low ,, ...	16″
,, pump plunger ,, ...	12″
Length of stroke	15″
Diameter of suction pipe	14″
,, discharge	12″
,, main discharge	16″

Two Babcock and Wilcox Water-tube Boilers, each having 526 square feet of heating surface and each capable of driving two engines together, each pumping the maximum quantity of sewage against the maximum head.

Pressure of steam 160 lbs. per square inch. A steam superheater of 88 square feet of heating surface is fitted to each boiler, which raises the temperature of the steam to a maximum of 100° F. above that due to the pressure. A fuel economiser of 258 square feet of heating surface raises the temperature of the feed from about 95° F. to 180° F.

Cost of Pumping for one month.

Item.	For 28 days.			Per Pump H. P. Hour.	Per Million Gallons raised 1 ft.	Average daily cost.		
	RS.	A.	P.	ANNAS.	ANNAS.	RS.	AS.	P
Coal at Rs. 15-2-0 average per ton	353	12	5	1·65	8·32	12	10	2
Stores—oil, waste, etc.... ...	72	4	5	0·34	1·70	2	9	3
Wages—driving staff, firemen, etc...	303	12	4	1·41	7·15	10	13	7
Repairs and replacements ...	250	4	0	1·17	5·89	8	15	0
Supervision and office staff ...	67	6	0	0·31	1·58	2	6	6
Depreciation on machinery at 5%	459	11	1	2·14	10·82	16	6	8
Total ...	1,507	3	1	7·02	35·46	53	13	2
Add depreciation on buildings, at 3% ...	45	0	4	0·21	1·06	1	9	8
Total cost all charges ...	1,552	3	5	7·23	36·52	55	6	10

Mean rate of pumping 24,300 gallons per hour, 21 feet head, 19 feet suction.

RAYAPURAM PUMPING STATION.

Description of Plant.

293. Two Worthington Triple Expansion Surface Condensing Direct Coupled Steam Pumping Engines, each capable of pumping 4,000 gallons of sewage per minute against a total maximum head, including friction, of 50 feet.

Diameter of high pressure cylinder	9″
,, intermediate ,, ...	14″
,, low ,, ...	22″
,, pump plunger	23½″
Length of stroke	18″
Diameter of suction pipe	27″
,, discharge	24″
,, main discharge	33″

Two Babcock and Wilcox water tube boilers, each having 1,426 square feet of heating surface and each capable of driving two engines pumping the maximum quantity of sewage against the maximum head.

Pressure of steam 140 lbs per square inch, a steam superheater of 170 square feet of heating surface is fitted to each boiler which raises the temperature of the steam to a maximum of 120° F above that due to the pressure.

A fuel economiser of 700 square feet of heating surface is built in the flues which raises the temperature of the feed from about 95° F. to 180° F.

Cost of Pumping for one month.

Item.	For 30 days.			Per P. H P. hour.	Per Million Gallons raised one foot.	Average Daily Cost.		
	RS.	A.	P.	Annas.	Annas.	RS.	A.	P.
Coal at Rs. 15-2-0 average per ton...	1,006	2	2	·98	4·97	33	8	7
Stores—oil, waste, etc.	105	11	4	·10	·52	3	8	5
Wages—driving staff, firemen, etc...	330	2	6	·32	1·63	11	0	1
Repairs and replacements ...	304	13	6	·30	1·51	10	2	7
Supervision and office staff ..	80	0	0	·08	·39	2	10	8
Depreciation of machinery at 5 % ..	640	12	6	·63	3·17	21	5	9
Total ...	2,467	10	0	2·41	12·19	82	4	1
Add depreciation of buildings at 5%	48	4	6	·05	·24	1	9	9
Total cost all charges ...	2,515	14	6	2·46	12·43	83	13	10

Mean rate of pumping 83,000 gallons per hour, 23 feet head, 25·5 feet suction.

294. The two following tables summarise the costs of pumping at the different stations :— Summary of costs of pumping.

Summary of Cost of Pumping per Pump H. P. hour at different Stations.

—	Mylapore.	Ice House Road.	Napier Park.	Lang's Garden.	DeMellow's Road.	Law College.	Raya-puram.
Coal at Rs. 15-2-0 average per ton	...	2·71	3·22	4·38	...	1·65	0·98
Liquid Fuel at As. 2·75 per gallon	1·66	...	...	...	1·51	...	...
Stores—oil, waste, etc. ...	0·58	0·31	0·13	0·17	0·28	0·34	0·10
Wages—Driving staff &c.	2·66	0·47	0·88	1·90	0·73	1·41	0·32
Repairs [illegible]ements.	2·41	0·78	1·13	1·28	1·74	1·17	0·30
Supervision & office staff...	0·57	0·10	0·11	0·21	0·11	0·31	0·08
Total ..	7·88	4·37	5·47	7·94	4·37	4·88	1·78

Comparative Statement showing the cost per hour of one P. H. P., B. H. P., I. H. P.

STATIONS.	P. H. P. hour.	B. H. P. hour.	I. H. P. hour.	Quantity pumped in gallons per hour.
	ANNAS.	ANNAS.	ANNAS.	
(I) Mylapore Pumping Station ...	7·88	2·41	1·20	14,300
(II) Ice House Road ,, ...	4·37	1·08	0 90	37,000
(III) Napier Park ,, ...	5·47	...	...	35,000
(IV) Lang's Garden ,, ...	7·94	...	3·01	15,500
(V) DeMellow's Road ,, ...	4·37	·99	·49	33,800
(VI) Law College ,, ...	4·88	...	...	24,300
(VII) Rayapuram ,, ...	1·78	...	...	83,000

295. It is interesting to note that the new machinery installed at Rayapuram Pumping Station is far more economical than any other pumping plant, in every item. The Law College plant is the next most economical in fuel. The cost at this station is, however, greatly increased owing to the small proportion of the total horse-power that is being used at the present time. The Lang's Garden Station costs are high for the same reason. At the Mylapore Station the sewage is only sufficient to keep the engines working for about 10 hours per day. In consequence the supervision and driving staff charges are exceptionally high. The experiments showed that—with the exception of the Law College, Rayapuram and Mylapore Stations—the pumping plant has to be overdriven in an endeavour to cope with the sewage that comes to the stations during the hours of maximum flow. New plant is urgently required not only for this reason, but also because the existing plant is worn out at all the stations except Law College and Rayapuram. Remarks on tests.

As is always found with sewage pumping machinery, the costs are very high compared with those for pumping clear water. With new pumps, properly designed, and especially made for pumping Madras sewage, greater economy will be obtained, especially if suitable drivers can be found. This is a very real difficulty, as there appears to be in South India no institution that gives the necessary training. A suitable technical school training followed by several years' workshop training would be a great advantage to those who wish to be efficient drivers.

Economy effected by new pumping plant.

296. As will be seen from the tables of the results of the tests of the pumps at all the existing pumping stations, the cost of pumping the sewage is very high. In order to ascertain the extent of saving which may be effected by improved type of plant, a comparison has been made between the old steam pumping plant at Rayapuram and the existing pumping plant. With the old pumping plant, the same boilers were used, but there was no econ[illegible]ser or superheater. The following table gives the results obtained :—

		Average No. of gallons pumped per day.	Average coal consumption per day.	Average P. H. P. hour.	Coal consumed in lbs. per P. H. P. hour.
			TONS		
New Engines.	Economiser off, Superheater off	1,671,666	2-11-3-12	15·17	16·66
	Economiser off, Superheater on	1,688,571	2-9-0-27	13·72	17·34
	Economiser on, Superheater off	2,090,000	2-6-0-0	14·49	15·1
	Economiser on, Superheater on	1,946,000	1-16-2-14	12·87	12·96
Old Engines.	Economiser off, Superheater off	1,137,500	3-19-2-14	7·609	49·41
	Economiser off, Superheater on	1,230,000	3-19-0-19	8 46	45·03
	Economiser on, Superheater off	1,365,000	3-15-3-0	9·297	39·33
	Economiser on, Superheater on	1,582,500	3-12-3-14	9·298	37·91

These are the results of experiments extending over about two months, and carried out under ordinary working conditions. The new engines had been working for eighteen months before the experiments were made.

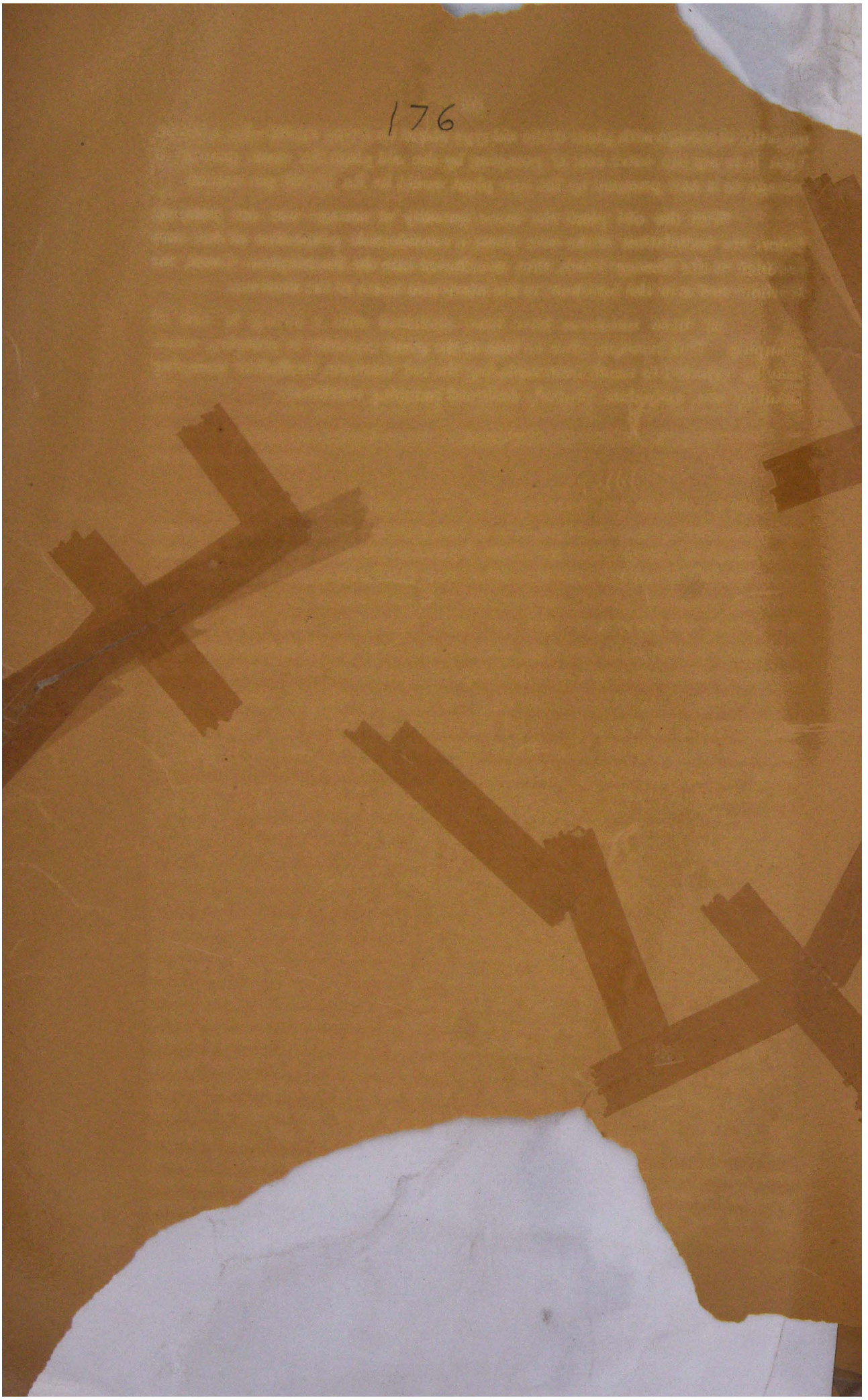
It will be seen that the average coal consumed per pump horse power hour is as follows:—

New engines under new conditions 12·96, old engines under old conditions 49·41, that is to say, that with a given quantity of coal, the new engines would do 3·8 times as much work as the old engines. As the cost of coal consumed per annum now is Rs. 12,000, the cost of pumping the same

quantity of sewage with plant of the old type would be 3·6 by 12,000=Rs. 4,56,000. That is to say the extra cost of pumping by the old plant the same quantity of sewage as is now pumped by the new plant would be Rs. 33,600 per annum.

With the old plant the same quantity of sewage was not pumped. Before the installation of the new plant, a considerable proportion of that now pumped to the Sewage Farm, then overflowed into the Buckingham Canal, the Harbour and over the foreshore to the north and south of the Harbour.

All these nuisances have been abolished with a saving in cost of pumping. This example gives an idea of the great economy in pumping which may be expected to result from replacing the old, worn-out, inefficient pumping plant by new, up-to-date, properly designed pumping machinery.



CHAPTER XVIII.

EXISTING CAST-IRON PUMPING MAIN.

297. Reasons for expecting cast-iron main to be inefficient. 298. Main too small to deal with sewage for which it was designed. 299. Experiment on carrying capacity of existing main. 300. Deductions from experiments. 301. Clearing Pumping Main. 302. Cost of work.

Reasons for expecting cast-iron main to be inefficient.

297. Experiments have been made to determine the conditions and carrying power of the existing long cast-iron pumping main.

This main is nine miles long. It begins at Mylapore and ends at the Sewage Farm, to which it conveys the sewage pumped at the eight existing stations—Mylapore, Ice House Road, Napier Park, Lang's Gardens, DeMellow's Road, Vepery, Law College and Rayapuram.

The writer has always felt that long pumping mains going up and down hill must be very unsatisfactory for conveying unscreened sewage. When it is remembered that in sewers running down hill, where gravity assists the flow, a velocity of $1\frac{1}{2}$ feet per second is required to move along even small quantities of silt, it appears obvious that, in order to move silt uphill against the force of gravity, a considerably greater velocity will be required. It is, therefore, to be expected that there will be a deposit of silt in all the low places in a long pumping main, unless the velocity is high. This opinion was confirmed when the pumping main near the Rayapuram Station was cut. At that point it was found that the pipe was full of silt up to two-thirds of its height. The silt consisted of a mixture of stones, sand and bricks, all matted together into a felt-like mass by leaves, sticks, etc. As a consequence, the writer thought it well to experiment with the existing cast-iron main from Mylapore to the Sewage Farm to ascertain whether its carrying capacity was much reduced. The result has been to show that the effective area of the main averages about one-half of its actual area.

Main too small to deal with sewage for which it was designed.

298. As far as can be ascertained, the basis for calculating the pumps and rising main was that they should be able to deal with 16 gallons per head per day calculated on the Census of 1891. This quantity is altogether too small

for it has been decided that the water-supply is to average 25 gallons per head per day, and the maximum sewage flow has been taken by the writer to be at the rate of 66⅔ gallons per head per day for a population which at present exceeds the 1891 population by some 14 per cent. The pumps and pumping mains will, therefore, have to deal with a quantity about five times greater than that for which the present installations were designed. To deal with the probable increase in population, a system with a capacity some six times that of the present system should be provided.

It was, therefore, decided to cut out certain areas from the cast-iron main and to provide them with other means of carrying off their drainage. From the considerations given in paragraph 297, it was thought that the main could not be as efficient as it should be. Before deciding on the measures to be recommended to improve the main, it was decided to make an experiment on its carrying capacity.

Experiment on carrying capacity of existing main.

299. The method of carrying out the experiment was to place a pressure gauge at each change of diameter and at each point where a branch pumping main joins. At the summits in the main, where gas was likely to collect, the main was tapped, and removable plugs were inserted, so that the gas could be allowed to escape. By this means, data were obtained for plotting hydraulic gradient curves. After some preliminary trials, the final experiment was carried out continuously from 6 A. M. to 2 P. M. on 19th October, 1912. Readings of the pressure gauges were taken every five minutes, while the self-recording gauges at the pumping stations gave continuous pressure diagrams. Readings of the Venturi Meter, and Recorder Counters were taken every fifteen minutes, and were compared with the continuous diagrams furnished by the automatic recorders which had been previously correctly calibrated for the purpose of the experiment. In order that the effect of the accumulated gas might be determined, part of the experiment from 6 A.M. to 8 A.M. was conducted without opening the cocks fixed at the summits. At 8 A.M. and at intervals of half an hour after that time, the cocks were opened and the gas allowed to escape. By this means, a number of hydraulic gradient curves were obtained. Of these, the maximum and minimum gradients (shown respectively by red and yellow curves) together with three intermediate gradients are shown on Drawing No. 6. The theoretical hydraulic gradient calculated for maximum flow is shown on the same Drawing by a yellow line. The corresponding rates of pumping as determined from the Venturi Meters at the pumping stations are also shown on the same Drawing. At the bottom of the Drawing is shown the actual sizes of pipes as laid, the areas silted up, the effective area of pipe, and the sizes of the equivalent pipes. On Plate XXIV are shown similar curves illustrating the extent to which the pipes are reduced in size by silt. From the diagram given on this Plate, it will be seen that the pressure in the pipe is very much greater than it would be, if the pipe had its full effective size. The increase in the pressure becomes greater the further the sewage is pumped. At Mylapore, the head is as much as 45 feet (or rather more than 82 per cent.) greater than it should be, that is to say, the cost of pumping at this station is very nearly doubled owing to the accumulated gas, silt and sediment in the pipe.

The following table gives some of the results of the experiments :

	Actual size of pipe.	Average equivalent size of pipe.	Area.	Rate of pumping through pipe.	Equal to	Velocity in pipe.	Hydraulic gradient.
	Inches.	Inches.	Square feet.	Gallons per hour.	Cubic feet per minute.	Feet per second.	
Mylapore Pumping Station to junction with 18 inches ...	12	8¾	·4185	15,000	40	1·6	1 in 700
Junction 12″—18″ to junction of Ice House Road Pumping Station Branch ...	18	9½	·4902	15,000	40	1·4	1 ,, 1,000
Ice House Road Branch to junction of Napier Park Pumping Station Branch ...	18	12¾	·8843	44,000	117	2·2	1 ,, 650
Napier Park Branch to junction of Lang's Garden Branch ...	27	15¾	1·3273	84,000	224	2·8	1 ,, 480
Lang's Garden Branch to junction of temporary Pumping Station, Vepery... ...	27	20	2·1655	108,000	285	2·2	1 ,, 1,130
Vepery junction to DeMellow's Road Pumping Station junction.	27	21	2·4053	133,000	355	2·5	1 ,, 840
DeMellow's Road junction to junction of 30″—33″ ...	30	22½	2·8050	155,000	416	2·5	1 ,, 880
Junction 30″—33″ to junction of Rayapuram and Law College Main 33″—36″.	33	23½	3·01	155,000	416	2·3	1 ,, 1,270
Junction 33″—36″ to Open Channel ...	36	33	5·939	298,000	790	2·2	1 ,, 1,900

NOTE.—The velocities above given are approximately the maximum velocities which are obtained in ordinary working of the sewage system. It is interesting to note that the silting up of the pipes continues until the area is so reduced that the velocity becomes about 2½ feet per second when apparently it ceases, the area being so reduced that the velocity serves to transport silt. The velocity is greatest between the Napier Park junction and the Lang's Garden junction. If the section of the pipe (Plate XXIV) is examined the reason for this is apparent; for between these two points there is a summit where the main is carried over the river Cooum. Thus the silt has not only to be transported, but it has also to be carried up hill and, as would be expected, a greater velocity is required. The results of these experiments on the cast-iron main go to confirm the figure fixed by the writer of 2⅛ feet per second as being the minimum which should be allowed for the sewers of Madras when flowing half full.

Deductions from experiments.

300. The volumes of gas that accumulated at summits of the main were so great that on opening the relief cock, gas would continue to rush out without intermission for half an hour before any liquid issued. This clearly indicates the necessity of providing a sufficient number of suitable air valves. The reduction of the effective area of the pipes by one-half, due mainly to the deposit of silt, points to the urgent necessity of fixing washouts at low places to enable the silt to be cleaned out of the pipe, but more important still is the provision of silt pits at all the pumping stations.

By means of proper silt pits all the heavier sand and grit would be separated. The finer material that would have to be pumped into the main, would be carried along by a comparatively slow stream. Thus, the silting up of

the main would be very much reduced, and such as occurred should be capable of being emptied at washouts, provided at all low places.

The provision of air valves and washouts should considerably increase the efficiency of the pumping main and the hydraulic gradient instead of being represented by the red line should approximate to the much flatter yellow line shown on Drawing No. 6.

Cleaning Pumping Main.

301. The results of the experiments described show how very important it is to get the main cleaned. To devise a method of cleaning the main economically is a difficult problem, in the solution of which no assistance can be obtained from previous experience. The usual plan of cleaning water mains by means of mechanical self-acting scrapers would be an expensive business for a main of the size under consideration, and further the amount of silt in the main would make it necessary to use a large number of machines of different sizes, and if a turbine with cutting blades were employed, it would probably destroy the top of the pipe. The main is destitute of hatch boxes and is very nearly devoid of scour pipes while the flow of sewage has to be maintained, as the pipe in question is the only channel by which the sewage of a large area of Madras can be led. In addition to actual difficulties in doing the operation, the question of cost is a very important one. The best plan would probably be to divide the main into comparatively small sections and provide it with sufficient hatch boxes and scour pipes, so as to enable it to be cleaned. The silt can then be loosened by a chain fitted with spikes, the scours opened and the silt washed out. By repeating this process a number of times, a large proportion of silt would be removed. A torpedo-shaped block could then be used for the final cleaning. The block would be so shaped that the front facing the flow would have a sharp taper while the back end would taper slowly in a stream-line form somewhat like that of a venturi tube, so as to minimise the energy consumed. This torpedo-shaped block would be made sufficiently short to travel round the corners without difficulty. It would be held back by means of stout cable and the pumps started. A high velocity would induce round the plug and this would have the effect of scouring out the material in the pipe. Controlled by the cable, the plug would be allowed to travel very slowly and the material would be cleaned off as it travels along. These operations would preferably be carried out from about 4 A.M. to 6 A.M. in the morning, when the flow of sewage to the pumping stations is small. Between midnight and 4 o'clock in the morning, the flow which is nearly all clean water, would be allowed to collect in the wells. At 4 o'clock, after inserting the block, the pumps would be set to work to pump the clean water and scour out the main, the scour out pipes being opened, so as to let the liquid carry away the silt with it.

Cost of work.

302. This is the scheme which the writer has in mind, but it will be necessary to experiment with short lengths before it can be decided what is the best plan to adopt. An item of Rs. 1,08,000 has been allowed in the estimates to cover the cost of this work.

CHAPTER XIX.

SURFACE WATER DRAINAGE OF MADRAS.

Drawings Nos. 61 *to* 68.

303. General method of dealing with surface water. 304. Stormwater of East Georgetown. **Harbour Overflow Intercepting Sewer proposed.**—305. Sewer to intercept overflows discharging into the Harbour. 306. Quantity of rainfall to be dealt with. 307. Estimates and drawing. 308. Cross section of sewer. 309. Manholes. 310. Materials to be used in construction. 311. Diversion of existing pipe sewer.

General method of dealing with surface water.

303. Madras city is very nearly flat, and a large portion of the sub-soil is porous The consequence is that after rain the water stands on the surface for some time before flowing off and a good deal of it soaks into the ground. That portion of the rainfall that does not soak into the ground, passes away slowly down natural drainage channels and artificial ditches. It thus causes nothing like the damage that would occur on the same area if the ground were steep and the rain-water were discharged quickly in rushing streams. In fact, beyond some inconvenience very little harm is done by rain-water, except to walls and houses built in mud. This, however, is a problem of building construction with which this report is not concerned. Surface water drainage is, therefore, not nearly so important in Madras, as it is in many other cities. At present it is carried away by ditches and old large masonry drains. The existing masonry sewage drains, when no longer required for sewage, may be linked up with side drains and utilised for surface water.

Now that a contoured Map of Madras has been prepared in the Special Works Department, the general lines of such additional surface water channels, as may be required, can be laid down. In only a few cases, however, is the matter urgent, and in most of these the remedy is to be found in the construction of short lengths of open channels or covered conduits.

Stormwater of East Georgetown.

304. In connection with abolishing the sewer overflows which discharge into the Harbour, the writer has had to investigate the question of the stormwater disposal of East Georgetown. The work is interesting as being the first attempt to design a stormwater sewer in Madras on a scientific basis. The rainfall statistics have had to be carefully investigated and the results may be given here in order that they may be placed on record to serve as a basis for the design of stormwater sewers in other areas of Madras, as they come to be required.

The sewer itself is part of the City Main Drainage and should be constructed by the Corporation. The cost, however, should be borne by the Port Trust, for the existing drains discharged into the sea before the Harbour came into existence, and it is solely for the benefit of the Harbour that it is now proposed to divert their discharge and carry it to the north of Clive Battery. Estimates of the cost amounting to Rs. 85,630 are given in Volume II, pp 196 to 198, but the sum is not included in the estimated cost of the City Main Drainage work.

In addition to this East Georgetown stormwater sewer, the only works connected with stormwater are the stormwater overflows provided at the different stations. (*See* Drawings 65 to 68). These are intended to carry away such of

the storm-water, that may gain access to the sewerage system, as the pumps are unable to deal with. Every effort will be made, however, to exclude storm-water, so that these storm overflows will rarely come into action.

Harbour Overflow Intercepting Sewer proposed.

Sewer to intercept overflows discharging into the Harbour.

305. For many years, in fact from before the Harbour was constructed, overflows for the Georgetown stormwater have discharged into the sea where the Harbour is now situated. Owing to complaints from the Chairman of the Madras Port Trust, the Special Engineer was instructed to prepare a scheme for intercepting the overflows and carrying away their contents to a point clear of the Harbour. In accordance with these instructions, a brick sewer 4,300 feet long, varying in diameter from 4 feet to 5 feet 3 inches has been designed. The total estimated cost of this is Rs. 85,630. The sewer is designed to carry off a discharge of 1 inch per hour over the area that drains to it.

Quantity of rainfall to be dealt with.

306. The object of the proposed intercepting sewer is to carry off the rainwater which falls on that part of Georgetown which lies roughly between the First Line Beach on the east and Thumbu Chetty Street on the west. It is of fundamental importance to decide how much rain shall be taken into the sewer. From figures in the writer's office which were obtained from the Government Astronomer, and abstracted by Mr. Griffith, when he was Corporation Engineer, it has been found that in 11 consecutive years (from 1896 to 1906) there were the following instances of *intense* rainfalls, *i.e.*, rainfalls *exceeding half an inch per hour* :—

Fall in inches in one hour.	Number of occasions.
0·50—0·59	73
0·60—0·69	61
0·70—0·79	28
0·80—0·89	28
0·90—0·99	27
1·00—1·19	22
1·20—1·39	13
1·40—1·59	12
1·60—1·79	2
1·80—2·09	5

During the same period the instances of *heavy* rainfalls, *i.e.*, *exceeding one inch per day* were as follows:—

Fall in inches in one day.	Number of occasions.
1·00—1·49	62
1·50—1·99	38
2·00—2·49	27
2·50—2·99	20
3·00—3·99	14
4·00—4·99	2
5·00—5·99	4
6·00—6·99	2
8·20	once (30-12-1903)
10·62	once (9-12-1901).

From these results, the writer estimates that the drain will be sufficiently large if it is capable of discharging a maximum of one inch of rainfall per hour

under a slight head and of carrying half an inch of rain per hour when the sewer is running a little more than half full in its upper reaches and slightly fuller in the lower reaches where the run-off will take some time to arrive, so that the rate of flow will have become less per acre of catchment. It is on this basis that the present design has been prepared.

On Drawings Nos. 61 to 64 accompanying this report, the hydraulic gradient line due to a flow of one inch of rain per hour over the areas drained, is shown by a dotted line, which, except in the lowest reaches, is above the top of the sewer. The hydraulic gradient, with a flow of half an inch of rain per hour, is shown by a dotted line which is about half way up the sewer at its two extremities.

It should be explained that the hydraulic gradient lines refer to the rate of flow which reaches the sewer and not to the rainfall. Except with a heavy fall of some duration the latter quantity is considerably in excess of the former. Thus in the case of a light fall, all the rain might soak into the ground so that there would be no flow at all to the sewer. With a heavy fall some would soak into the ground, while that portion that falls on the areas close to the sewer would reach the sewer more quickly than that portion which descended on more distant areas, in this way the discharge becomes spread over a longer period than the rainfall, and its intensity is reduced accordingly.

307. The intercepting sewer begins at its top end opposite Mucar Nallamu... Estimates ... drawing
Chetty Street, and runs in a northerly direction along First Line Beach, past Clive Battery to a point opposite Rayapuram Railway Station. Here it terminates 50 feet south of the proposed north arm of "Lawley Haven" and it is proposed to leave the continuation of the sewer from this point, and the provision of the sea outfall, to be carried out by the Madras Port Trust and incorporated in the design and construction of the north arm of the new "Lawley Haven" which the Port Trust intend to construct as a harbour for fishing boats. The sewer invert at the north end is at Mean Sea Level, but to avoid splashing and possible nuisance, it will be an advantage if the actual outfall discharges in a downward direction at some point below low tide with the outlets completely submerged. The sewer has been kept as shallow as possible to minimise the cost of construction. Contrary to the usual practice, the invert, and not the axes of the sewer, have been kept in one line. The object of this is to ensure a rapid discharge with the smaller rainfalls. With heavy rainfalls the discharge will be rapid in any case. The fall available is the difference in level between Mean Sea Level and the Invert Level of the first overflow (No. 1) and amounts to 5·14 feet. By keeping the invert at an even gradient, the discharge for rainfall flowing up to about $\frac{3}{4}$ inch per hour is considerably increased over what it would be, if the inverts were dropped as is the usual and correct practice in ordinary sewer construction.

On its way northwards, the sewer will pick up overflows opposite :—

(1) Mucar Nallamuthoo Chetty Street.

(2) Arbuthnot Lane.

(3) Jaffar Sirang Street.

(4) Gopaul Chetty Street.

(5) Varadapparaju Mudaly Street.

If continued beyond Clive's Battery, it will intercept the north Main Drain and also two other outlets which at present discharge into the area proposed for "Lawley Haven."

It is proposed to lay the sewer on the east side of North Beach Road between the tram line and the foot-path and as close as possible to the east building line of the road.

The following table shows overflows intercepted, areas drained, sizes of sewers, etc. :—

Outlet to be intercepted.	Area draining to Outlet.	Flow from area for 1 inch rain per hour.	Quantity to be carried off by intercepting Sewer.	Size of intercepting Sewer.	Gradient.	Length.	Sewer flowing full.	
							Velocity.	Discharge.
	ACRES.	C. FT. MIN.	C. FT. MIN.	DIA.		FEET.	FT. SEC.	C. FT. MIN.
Overflow No. 1	55·4	3,352	3,352	4′ 0″	$\frac{1}{750}$	1,130	4·53	3,414
,, ,, 2	18·3	1,107	4,459	4′ 6″	$\frac{1}{820}$	870	4·8	4,470
,, ,, 3	11·1	672	5,131	4′ 9″	$\frac{1}{820}$	450	4·85	5,163
,, ,, 4	3·8	230	5,361	4′ 9″	$\frac{1}{760}$	410	5·05	5,363
,, ,, 5	28·0	1,694	7,055	5′ 3″	$\frac{1}{750}$	980	5·43	7,050
ain Drain" nd Minor Outlets.	182	11,000	18,055	8′ 0″ D shape.	$\frac{1}{1,300}$	460	5·40	18,016
						4,300		

* Required only if sewer is carried northwards beyond Clive's Battery.

ss ction of ewer.

308 The circular section has been adopted for the major portion of the sewer, because in the circumstances, it is the most economical and efficient. The length of 460 feet at the north end of the sewer, 8 feet internal width and height, has been designed "D" shaped with the object of slightly reducing the height and obtaining more cover on top without materially increasing the width of cutting

Manholes.

309. The junction manholes at the points of intercepting the existing overflows are designed to be of simple form, substantially built, and arranged so as to guide the incoming flow well in the direction of flow in the intercepting sewer. The ordinary manholes will furnish means of ingress to the sewer. All manholes are to be covered with strong cast-iron manhole covers of the closed pattern.

Materials to be used in construction.

310. It is proposed to construct the intercepting sewer of brickwork and concrete, the shallower portions of diameters 4 feet, 4 feet 6 inches and 4 feet 9 inches, being built in "combination mortar" and the portions 5 feet 3 inches diameter and 8 feet "D" shape which will be in wet ground, will be constructed in cement mortar up to the level of the springing of the arch, the arch itself being built in combination mortar. The inside of the sewer for its whole length will be smoothly plastered with 3 to 1 cement mortar $\frac{5}{8}$ inch thick, and the extrados of the arch with combination mortar $\frac{5}{8}$ inch thick ; this should make the sewer perfectly watertight and will protect the brickwork

Diversion of existing pipe sewer.

311. A length of about 620 feet of the existing 12-inch pipe sewer, which will be interfered with by the intercepting sewer at its south end will require to be diverted and three new manholes built. This work is included in the estimate.

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CHAPTER XX.

MADRAS CITY MUNICIPAL ACT.

INTRODUCTION.

1. Madras City Municipal Act of 1904 requires revision. 2. Legal opinion should be obtained. 3. Dividing line between Act and Byelaws. 4. Standard Regulations required to ensure uniformity of practice. 5. Power to make Byelaws. 6. Interpretation of terms. 7. Division of Act.

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INTRODUCTION.

Madras City Municipal Act of 1904 requires revision.

1. Before formulating a set of Drainage Byelaws, it is necessary to consider the drainage clauses that are required in the Municipal Act. There is no doubt that the Madras City Municipal Act of 1904 needs revision in the sections that deal with drainage and water-works.

In the writer's report of September 1911 on the Madras City Water Distribution Scheme, the amendments desirable in the water-works clauses were set out. The drainage clauses require so much revision that it appears desirable to re-write them altogether, and this has accordingly been done. While some of the proposed clauses are original, others have been extracted from the Bombay Municipal Act and English Public Health Acts, with such modifications as appear desirable for Madras.

Legal opinion should be obtained.

2. To ensure that the drainage clauses here put forward are valid, they should be submitted to high legal authority. In some towns, where legal advice has not been obtained, it has been found that the Act could not be enforced, and considerable delay has been caused while the necessary amendments were made.

Dividing line between Act and Byelaws.

3. It is difficult to decide what shall be the dividing line between the Act and Byelaws. In a general way, the clauses of the Act have been so framed as to state what is to be done, and the President, Standing Committee or Corporation, pass the necessary orders. The Byelaws are more in the nature of a specification describing how drainage work is to be carried out, and in most cases the Engineer decides whether or not they have been complied with. It is impossible, however, to keep this line of division absolutely rigid, and it may be that some of the clauses of the Act would be more appropriately included in the Byelaws. It will be observed that the "Owner" is dealt with throughout, the "Occupier" is not recognised. This has been done in order to make it as easy as possible to enforce the requirements of the Act and Byelaws. The proposed clauses of the Act and the proposed Byelaws refer only to the Water Carriage Drainage System of the City.

Refuse disposal has been left to be dealt with by the Health Officer who, it is understood, is framing regulations for his department.

Standard regulations required to ensure uniformity of practice.

4. A considerable amount of time has been devoted to the preparation of the clauses here put forward, and it is suggested that when considering them, Government should bear in mind the question of so framing both the Act and the Byelaws that they may be taken as a standard for the Madras Presidency. It appears to the writer highly important that the practice in this Presidency should be standardized so far as local variations in conditions permit. Drainage works are now being undertaken by almost all the important towns in South India, and it will be of very great advantage not only to the inhabitants, but also to architects, engineers, builders and plumbers, if a standard code of rules is adopted before first-class sanitary fittings and drainage works are installed. If the rules are different in different Municipalities, there will be much confusion. Further, merchants will have to stock several classes of pipes, water-closets, flushing cisterns, lavatory basins, and other goods. In England, difficulties arising from this cause have led to a strong demand for standardization

which has resulted in the formation of committees, representing all interested parties, to draw up standard rules and regulations. Some such procedure might with advantage be adopted for Madras Presidency, or, better still, for the whole of India.

In Madras City, first-class drainage works have already been carried out in connection with hospitals, hotels, clubs, banks and other public offices, and a considerable demand is also arising for first class drainage of private residences. A complete set of regulations is, therefore, urgently needed in order that house-owners and business firms may know exactly the class of work required by the Corporation.

Power to make Bye-laws.

5. Under the Byelaws clauses of the Act, it is recommended that the Corporation be authorised to make Byelaws for :—

Regulating the dimensions, materials, form and mode of construction, and the maintaining, cleansing and repairing, of the pipes and drains communicating with the Municipal drainage system, and of the traps and other apparatus connected therewith. This clause is briefer than the clauses of the existing Act, but is believed to be sufficient.

Interpretation of terms.

6. It is assumed that the definition clauses of the Act will be carefully revised. The following are recommended as particularly referring to the drainage clauses :—

"*Drain*" *means a channel for conveying by gravity liquid matter which may or may not contain solid matter.*

"*Sewage*" *means any liquid carrying organic matter liable to rapid decomposition.*

"*Sewage System*" *means a system of drains specially designed to convey sewage.*

Division of Act.

7. For convenience the Act has been considered as divided into Main Divisions, which are again sub-divided into sections with their clauses, paragraphs and sub-paragraphs. Thus the powers of the President to require an owner to construct a drain are given in Division No..... Section II, clause 12, paragraph (1), sub-paragraph (*a*). This nomenclature is of course arbitrary, and may be altered to suit whatever system of dividing up the Act is eventually considered best. Such alteration would entail the changing of a few words only.

PROPOSED DRAINAGE CLAUSES FOR
MADRAS CITY MUNICIPAL ACT.

Division No.

DRAINS AND DRAINAGE WORKS.

Section I.—Municipal Drains.

Municipal drains to be under the control of the President.

1. All drains vesting in or belonging to the Corporation—which in this Act are referred to as "Municipal drains"—shall be under the control of the President.

Vesting of water-courses.

2. Any natural water-course heretofore belonging to His Majesty by which rain water or drainage of any kind is carried, may, on application to Government made by the President with the previous approval of the Standing Committee, be vested in the Corporation, provided that

(*a*) it shall be in the discretion of Government in each case to determine whether a particular water-course applied for shall be so vested, and

(*b*) a Resolution of Government declaring that a water-course so applied for may be made over to the Corporation shall, from the date thereof, operate to vest such water-course in the Corporation.

Drains to be constructed and kept in repair by the President

3. (1) The President shall maintain and keep in repair all Municipal drains and, when authorised by the Corporation in this behalf, shall construct such new drains as shall from time to time be necessary for effectually draining the City.

(2) The President shall also, in the case of any street in which there is a Municipal drain, construct* at the charge of the Municipal fund such portion of the drain of any premises to be connected with such Municipal drain as it shall be necessary to lay under any part of such street, and the portion of any connecting drain so laid under the street shall vest in the Corporation and be maintained and kept in repair by the President.

Power for making drains

4. (1) The President may construct or make any Municipal drain or other work connected with the draining of the City through, in, on, over, across or under any street, or any place laid out as or intended for a street, or under any cellar or vault which may be under any street, and after giving reasonable notice in writing to the owner or occupier, in, on, over, through, across or under any land whatsoever within the city, or, for the purpose of outfall or disposal of sewage, without the city.

(2) The President may enter upon, and construct any new drain in the place of an existing drain in any land wherein any Municipal drain has been already lawfully constructed, or repair or alter any Municipal drain so constructed.

(3) In the exercise of any power under this Act, as little damage as possible shall be done, and (with the sanction of the Standing Committee)

* This may require modification, because the Corporation have decided tentatively that in the case of new houses, the cost of the whole of the connection from the sewer should be borne by the house-owner.

compensation shall be paid by the President to any person who sustains damage by the exercise of such power.

(4) If the Corporation construct any drain, or other work connected with the drainage of the city across or alongside a line of railway, tramway, culvert, electric cable, drain, building, structure, or other work, they may, with the sanction of the local Government and at the cost of the Municipal fund, require the owners thereof to raise, lower, remove or otherwise alter the said railway tramway, culvert, electric cable, drain building, structure, or other work.

Buildings, etc., not to be erected without permission over drains.

5. (1) Without the written permission of the President, no building, wall or other structure shall be erected, and no street or railway, tramway, culvert, electric cable, drain, building, structure, or other work, shall be constructed over, under, across or alongside any Municipal drain.

(2) If any building, wall or any other structure be so erected, or any street or railway be so constructed, the President may, with the approval of the Standing Committee, remove or otherwise deal with the same as he shall think fit, and the expenses thereby incurred shall be paid by the owner.

Alteration and discontinuance of drains.

6. The President may enlarge, diminish, lengthen, or shorten, repair or renew, or in any way modify or improve any Municipal drain or any other work connected with the drainage of the City and may discontinue, close up, remove or destroy any such drain or such other work when in his opinion it is desirable to do so.

Cleansing drains.

7. For the purpose of constructing or maintaining any work in connection with the drainage of the city, the President may, when duly authorised in this behalf, construct, set up and work such reservoirs, sluices, engines and other works, as he shall from time to time deem necessary.

Section II.—Drainage Work of Private Streets and Premises.

Power to connect drains of private streets with Municipal drains.

8. The owner of a private street shall be entitled to have a drain laid in such street, and shall be entitled to have such drain connected with a Municipal drain, subject to the following conditions, namely:—

(*a*) before commencing to construct such drain, the owner of the street shall submit to the President a plan of the street, bearing the signature of a competent Surveyor approved by the President in token of its having been made by him or under his supervision, and drawn to such a convenient scale as the President shall require, and there shall be shown on such plan the position, course and dimensions of the proposed drain, and all its appurtenances with a section or sections thereof, with levels reduced to G. T. S. datum and such other particulars in relation thereto as the President shall require, and the construction of any such drain shall not be proceeded with without the approval in writing or contrary to the directions of the President;

(*b*) the drain of such private street shall, at the expense of the owner of the street, be constructed at such a gradient and of such dimensions, material and description, and be connected to the Municipal drain in such manner as the President shall direct;

(*c*) the President may, if he thinks fit, construct such part of such drain and such part of the work necessary for connecting the same to the Municipal drain as shall be in or under any public street or place vesting in the Corporation and, in such case, the expenses incurred by the President shall be paid by the owner of the private street

Power of owners and occupiers of premises to drain into Municipal drains.

9. The owner of any premises shall be entitled to have the drainage of such premises connected to a Municipal drain, provided that he first obtains the written permission of the President and that he complies with such conditions as are laid down in the bye-laws to govern house drainage.

Connections with Municipal drains not to be made except in conformity with clauses 8 and 9.

10. No person shall, without written permission from the President, make or cause to be made any connection of a drain belonging to himself or to some other person with any Municipal drain, and the President may close, demolish, alter or re-make any such connection made in contravention of this clause or of clauses 8 and 9, and the expenses incurred by the President in so doing shall be paid by the owner of the street, or premises, for the benefit of which the connection was made.

Rights of owners and occupiers of premises to carry drains through land belonging to other persons.

11. (1) If it shall appear to the President that the most convenient means by which the owner of any premises can cause his drainage to be connected with a Municipal drain, is by carrying the same in, on, over, through, across, or under any land belonging to some person other than the said owner of the premises to be drained, the President, after allowing to the owner of the land a period of four weeks in which to state in writing any objection, may, if no objection is raised, or if any objection which is raised appears to him invalid or insufficient, by an order in writing, authorise the said owner of the premises to be drained to construct the required drain in, on, over, through, across, or under the said land in such manner as the President shall think fit to allow.

(2) Every such order, bearing the signature of the President, shall be a complete authority to the person in whose favour it is made, or to any agent or person employed by him for this purpose, after giving to the owner of the land seven days written notice of his intention so to do, to enter upon the said land with assistants and workmen, at any time between 6 A.M and 6 P.M on ordinary working days, and to execute the necessary work.

(3) Subject to all other provisions of this Act, the owner of any premises, or any agent or person employed by him for this purpose, may, after obtaining a written order from the President and after giving to the owner of any land, wherein a drain has been already lawfully constructed for the drainage of his said premises, seven days written notice of his intention so to do, enter upon the said land with assistants and workmen, at any time between 6 A.M. and 6 P.M. on ordinary working days, and construct a new drain in the place of the existing drain or repair or alter any drain so constructed.

(4) In executing any work under this section, as little damage as possible shall be done, and the owner of premises for the benefit of which the work is done shall—

(*a*) cause the work to be executed with the least practicable delay ;

(*b*) fill in, re-instate and make good, at his own cost and with the least practicable delay the ground or portion of any building or other construction opened, broken up or removed for the purpose of executing the said work ;

(*c*) pay compensation to any person who sustains damage by the execution of the said work.

(5) If the owner of any land, in, on, over, through, across, or under which a drain has been constructed under this clause whilst such land was unbuilt upon, shall, at any time afterwards, desire to erect a building on such land, the President shall, by written notice, require the owner of the premises for the benefit of which such drain was constructed to close, remove or divert the same in such manner as shall be approved by the President, and to fill in, re-instate and make good the land as if the drain had not been constructed in, on, over, through, across, or under the same: provided that no such requisition shall be made, unless, in the opinion of the President, it is necessary or expedient, in order to admit of the construction of the proposed building or the safe enjoyment thereof, that the drain be closed, removed or diverted.

President may enforce drainage of undrained premises situate within a hundred and fifty feet of Municipal drain.

12. Where any premises are, in the opinion of the President, without sufficient means of effectual drainage and a Municipal drain is situated at a distance not exceeding one hundred and fifty feet from some part of the boundary of the said premises, the President may, by written notice, require the owner of the said premises :—

(*a*) to construct or make a drain or drains of such material, dimension and description and laid at such level and according to such alignment and with such fall and outlet as may appear to the President necessary ;

Provided that, where any premises have already been drained under Municipal rules in force at the time, and have to be re-drained, no such requisition shall be made without the previous sanction of the Standing Committee ;

(*b*) to provide and set up all such appliances and fittings as may appear to the President necessary for the purpose of gathering and receiving the drainage from, and conveying the same off, the said premises and of effectually flushing such drain and every fixture connected therewith ;

(*c*) to remove any existing drain, or other appliance or thing used or intended to be used for drainage, which may be injurious to health.

President may enforce drainage of undrained premises not situate within a hundred and fifty feet of a Municipal drain.

13. (1) Where any premises are, in the opinion of the President, without sufficient means of effectual drainage, but no Municipal drain is situated at a distance not exceeding one hundred and fifty feet from some part of the said premises, the President may, by written notice, require the owner of the said premises—

(*a*) to construct a drain up to a point to be prescribed in such notice, but not distant more than one hundred and fifty feet from some part of the said premises, or

(*b*) to construct a closed cesspool of such material, dimension and description in such position, at such level, as the President thinks necessary and to construct a drain or drains emptying into such cesspool.

(2) Any requisition for the construction of any drain under paragraph (1) may comprise any detail specified in sub-paragraphs (*a*), (*b*) or (*c*) of clause 12.

Power of President to drain premises in combination.

14. (1) Where the President is of opinion that any group or block of premises, any part of which is situate within one hundred and fifty feet of a Municipal drain, already existing or about to be constructed, may be drained more economically or advantageously in combination than separately, the President may, with the approval of the Standing Committee, cause such group or block of premises to be drained by such method as appears to the President to be best suited therefor and the expenses incurred by the President in so doing shall be paid by the owners of such premises in such proportions as the Standing Committee may decide or allocate.

(2) Not less than fifteen days before any work under this section is commenced, the President shall give written notice to the owners of all the premises to be drained of—

(*a*) the nature of the intended work,

(*b*) the estimated expenses thereof, and

(*c*) the proportion of such expenses payable by each owner.

(3) The owners for the time being of the several premises constituting a group or block drained under para. (1) shall be the joint owners of every drain constructed, erected or fixed, or continued for the special use and benefit only of such premises and shall in the proportion in which it is determined that the owners of such premises are to contribute to the expenses incurred by the President under paragraph (1), be responsible for the expense of maintaining every such drain in good repair and efficient condition.

President may close or limit the use of existing private drains.

15. (1) Where a drain connecting any premises with a Municipal drain is sufficient for the effectual draining of the said premises and is otherwise unobjectionable, but is not, in the opinion of the President, adapted to the general drainage system of the city, or of the part of the city in which such drain is situated, the President, with the approval of the Standing Committee, may—

(*a*) subject to the provision of para. (2) discontinue or destroy the said drain and cause any work necessary for that purpose to be done;

(*b*) direct that such drain shall, from such date as he prescribes in this behalf, be used for sullage and sewage only, or for rain-water only, or for unpolluted sub-soil water only, or for both rain-water and unpolluted sub-soil water only, and by written notice require the owner of the premises to make an entirely distinct drain for rain-water or unpolluted sub-soil water, or for both rain-water and unpolluted sub-soil water, or for sullage and sewage.

(2) No drain may be closed, discontinued or destroyed by the President under para. (1) sub-para. (*a*), except on condition of his providing another drain as

effectual for the drainage of the premises and communicating with a Municipal drain; and the expenses of the construction of any drain so provided by the President and of any work done under para. (1), sub-para. (*a*), shall be paid by the President.

(3) Any requisition made by the President under para. (1), sub-para. (*b*), may embrace any detail specified in sub-paras (*a*) or (*b*) of clause 12.

Vesting and maintenance of drains for sole use of properties.

16. Subject to the provisions of clause (3), para. (2), every drain which has been constructed, erected or set up, whether at the expense of the Corporation or not, or which is continued, for the sole use and benefit of any premises shall—

(*a*) Notwithstanding anything contained in section 25, vest in the owner of such premises on and from the day of 191 , and

(*b*) be maintained in good repair and efficient condition by such owner of such premises.

New buildings not to be erected without drains.

17. (1) It shall not be lawful—

(*a*) to erect, re-build, alter, or add to any building until drains be constructed of such dimension, materials and description, at such level and with such fall, as shall appear to the President to be necessary for the effectual drainage of such building;

(*b*) occupy any building newly erected, rebuilt, added to or altered until there have been provided for and set up in such building and in the premises appurtenant thereto, all such appliances and fittings as may appear to the President to be necessary for the purposes of gathering and receiving the drainage from, and conveying the same off, the said building and the said premises, and of effectually flushing the said drains and every fixture connected therewith.

(2) The drains to be constructed as aforesaid shall be connected with a Municipal drain, if such a drain is situated at a distance not exceeding one hundred and fifty feet from the boundary of the premises in which such building is situated, but if no such Municipal drain is within that distance, then such drain shall empty into such cesspool as the President directs.

Excrementitious matter not to be passed into cesspools.

18. No person shall, except with the permission of the President, pass or cause or permit to be passed any excrementitious matter into any cesspool made or used under clause 13 or 17, or into any drain communicating with any such cesspool.

Obligation of owners of drains to allow use thereof or joint ownership therein to others.

19. Every owner of a drain connected with a Municipal drain or cesspool shall be bound to allow the use of it to others, or to admit other persons as joint owners thereof, on such terms as may be prescribed under clause 21.

How right of use or joint ownership of a drain may be obtained by a person other than the owner.

20. Any person desiring to drain his premises into a Municipal drain or cesspool, through a drain of which he is not an owner, may make a private arrangement with the owner for permitting his use of the drain, or may apply to the President for authority to use such drain or to be declared joint owner thereof.

President may authorise person other than the owner of a drain to use the same or declare him to be a joint owner thereof.

21. (1) Where the President is of opinion, whether in receipt of such application or otherwise, that the most convenient means by which the owner of any premises can cause the drain of such premises to empty into a Municipal drain or cesspool, is through a drain communicating with such Municipal drain or cesspool aforesaid, but belonging to some person other than the said owner the President may, with the approval of the Standing Committee, by an order in writing, either authorise the said owner to use the drain or declare him to be a joint owner thereof, on such conditions as to the payment of rent or compensation and as to connecting the drain of the said premises with the communicating drain and as to the respective responsibilities of the parties for maintaining, repairing, flushing, cleaning and emptying the joint drain, or otherwise, as may appear to him equitable.

(2) Every such order bearing the signature of the President shall be a complete authority to the person in whose favour it is made, or to any agent or person employed by him for this purpose, after giving or tendering to the owner of the drain the compensation or rent specified in the said order and otherwise fulfilling as far as possible, the conditions of the said order, and after giving to the owner of the drain seven days' written notice of his intention so to do, to enter upon the land in which the said drain is situate with assistants and workmen, at any time between 6 A.M. and 6 P.M., and, subject to all provisions of this Act, to do all such things as may be necessary for :—

(*a*) connecting the two drains ; or

(*b*) renewing, repairing or altering the connection ; or

(*c*) discharging any responsibility attaching to the person in whose favour the President's order is made for maintaining, repairing, flushing, cleaning or emptying the joint drain or any part thereof.

(3) In respect of the execution of any work under para. (2), the person in whose favour the President's order is made shall be subject to the same restrictions and liabilities which are specified in para. (4) of clause 11.

Sewage and rain-water drains to be distinct.

22. Whenever it is provided in this Section that steps shall or may be taken for the effectual drainage of any premises, it shall be competent to the President to require that there shall be one drain for sullage, excrementitious matter and polluted water, and another and entirely distinct drain for rain-water or unpolluted sub-soil water, or for both rain-water and unpolluted sub-soil water, each emptying into separate Municipal drains or other suitable places specified by the President.

Drains not to pass beneath buildings.

23. Except with the written permission of the President and in conformity with the bye-laws, in this behalf, no drain shall be so constructed as to pass beneath any part of a building.

Position of cesspools.

24. No person shall construct a cesspool—

(*a*) beneath any part of any building, or within fifty feet of any lake, tank, reservoir, stream, spring or well ; or

(*b*) upon any site or in any position which has not been approved in writing by the President.

Right of Corporation to drains, &c., constructed, &c., at charge of Municipal fund on premises not belonging to the Corporation.

25. All drains, ventilation-shafts and pipes and all appliances and fittings connected with drainage works constructed, erected or set up at the charge of the Municipal fund upon premises not belonging to the Corporation, whether before or after the passing of this Act, and otherwise than for the sole use and benefit of the said premises shall, unless the Corporation has otherwise determined or shall at any time otherwise determine, vest, and be deemed to have always vested in the Corporation.

All drains and cesspools to be properly covered and ventilated.

26. (1) Every drain and cesspool, whether belonging to the Corporation or to any other person, shall be provided with proper traps and coverings and with proper means of ventilation.

(2) The President may, by written notice, require the owner of any drain or cesspool not belonging to the Corporation to provide and apply to the said drain or cesspool such trap and covering and such means of ventilation as would be provided and applied if such drain or cesspool belonged to the Corporation.

Affixing of pipes for ventilation of drains, etc.

27. (1) For the purpose of ventilating any drain or cesspool, whether belonging to the Corporation or to any other person, the President may erect upon any premises or affix to the outside of any building or to any tree any such shaft or pipe as shall appear to the President necessary and cut through any projection from any building (including the eaves of any roof thereof) in order to carry up such shaft or pipe through any such projection; and lay in, through, on, over, or under any land, such appliances as may in the opinion of the President be necessary for connecting such ventilating shaft or pipe with the drain or cesspool intended to be ventilated.

(2) Provided that any shaft or pipe so erected or affixed shall—

(*a*) not terminate within 20 feet distance of any window or opening into any building, nor below such window or opening.

(*b*) if the same be affixed to a wall supporting the eave of a roof, be carried up at least two feet higher than such eave;

(*c*) be erected or affixed so as to create the least practicable nuisance or inconvenience to the inhabitants of the neighbourhood;

(*d*) be removed by the President to some other place, if at any time the owner of the premises, building or tree upon or to which the same has been erected or affixed is desirous of effecting any change in his property which either cannot be carried out, or cannot without unreasonable inconvenience be carried out, unless the shaft or pipe is removed.

(3) If the President declines to remove a shaft or pipe under sub-para. (*d*), the owner of the premises, building or tree, upon or to which the same has been erected or affixed, may apply to the Chief Judge of the Small Cause Court; and the said Chief Judge may, after such inquiry as he thinks fit to make, direct the President to remove the shaft or pipe, and it shall be incumbent on the President to obey such order.

(4) Where the owner of any building or land cut through, opened or otherwise dealt with under para. (1) is not the owner of the drain or cesspool intended to be ventilated, the President shall, so far as is practicable, re-instate and

make good such building, and fill in and make good such land, at the charge of the Municipal fund.

Section III.—Disposal of Sewage.

Appointment of places for emptying of drains and disposal of sewage.

28. The President may cause all or any Municipal drains to empty into the sea or other place, whether within or without the city, and dispose of the sewage at any place, whether within or without the city, and in any manner, which he shall deem suitable for such purpose: Provided that—

(*a*) the President shall not cause any Municipal drain to empty into any place into which a Municipal drain has not heretofore emptied, or dispose of sewage at any place or in any manner at or in which sewage has not heretofore been disposed of, without the sanction of the Corporation;

(*b*) any power conferred by this clause shall be exercised in such manner as to create the least practicable nuisance;

(*c*) no Municipal drain shall be made to empty into any place, and no sewage shall be disposed of at any place or in any manner which Government shall disallow.

Provision of means for disposal of sewage.

29. (1) For the purpose of receiving, storing, disinfecting, distributing or otherwise disposing of sewage, the President may, when duly authorised in this behalf—

(*a*) construct any work within or without the city;

(*b*) purchase or take on lease any land, building, engine, material or apparatus, either within or without the city;

(*c*) enter into an arrangement with any person, for any period not exceeding twenty years, for the removal or disposal of sewage within or without the city.

(2) Provided that any power conferred by this clause shall be exercised in such manner as to cause the least practicable nuisance.

Section IV.—Water-closets, Privies, Urinals, etc.

Construction of water-closets, privies, etc.

30. (1) It shall not be lawful to construct any water-closet or privy, latrine, urinal, or bath or washing place, for any premises except with the written permission of the President and in accordance with such terms, not being inconsistent, with any bye-laws for the time being in force as he may prescribe.

(2) In prescribing any such terms the President may determine in each case—

(*a*) whether the premises shall be served by water-closets, privies, latrines, urinals, or bathing or washing places or by any combination of these;

(*b*) what shall be the site or position of each water-closet, privy, latrine, urinal or bathing or washing place, and the number of each.

(3) If any water-closet, privy, latrine, urinal or bathing or washing place is constructed on any premises in contravention of para. (1), the President may, after giving not less than ten days' notice to the owner of such premises,

close such water-closet, privy, latrine, or urinal, bathing or washing place and, with the previous approval of the Standing Committee, alter or demolish the same, and the expense incurred by the President in so doing shall be paid by the owner.

Water-closet and other accommodation in buildings newly erected or re-erected.

31. (1) It shall not be lawful to erect, rebuild, alter or add to any building for, or intended for, human habitation, or at or in which, labourers or workmen are to be employed, without such water-closet, privy, latrine or urinal accommodation, and such accommodation for bathing or for the washing of clothes and domestic utensils, as the President may prescribe.

(2) In prescribing any such accommodation, the President may determine in each case—

(*a*) whether such building shall be served by water-closets, privies, latrines, urinals, or bathing or washing places or by any combination of these.

(*b*) what shall be the site or position of each water-closet, privy, latrine, urinal or bathing or washing place, and the number of each.

Where there is no such accommodation or the accommodation is insufficient or objectionable.

32. (1) Where any premises are without a water-closet or privy, latrine or urinal, or bathing or washing place, or if the President is of opinion that the existing water-closet, privy, latrine or urinal, or bathing or washing place, accommodation available for the persons occupying or employed in any premises is insufficient for each sex, or on any sanitary grounds objectionable, the President may, with the previous approval of the Standing Committee, by written notice, require the owner of such premises—

(*a*) to provide such, or such additional, water-closet, privy, latrine, urinal, or bathing or washing place accommodation as he prescribes;

(*b*) to make such structural or other alterations in the existing water-closet, privy, latrine, urinal, or bathing or washing place, accommodation as he prescribes; or

(*c*) to substitute water-closet accommodation for any privy accommodation.

(2) Provided that any requisition under Sub-section (1) may comprise any detail specified in Sub-section (2) of Section 31.

(3) Provided also that where the water-closet, privy, latrine, urinal, or bathing or washing place accommodation of any premises—

(*a*) has been, and is being, used in common by the persons occupying or employed in such premises and any one or more other premises, or

(*b*) is in the opinion of the President likely to be so used,

the President may, if he is of opinion that such accommodation is sufficient to admit of the same being used by all the persons occupying or employed in all such premises, direct in writing that separate water-closet, privy, latrine, urinal or bathing or washing place accommodation need not be provided on or for each of such other premises.

(4) Provided also that the President may, if he is of opinion that there is sufficient Municipal latrine accommodation available for all the persons occupying or employed in any premises, direct that separate water-closet, privy, latrine or urinal accommodation need not be provided for such premises.

Power to require privy accommodation to be provided for factories, etc.

33. Where it appears to the President that any premises are, or are intended to be, used as a market, railway station, dock, wharf or other place of public resort, or as a place in which persons exceeding twenty in number are employed in any manufacture, trade or business or as workmen or labourers, the President may, by written notice, require the owner of the said premises to construct a sufficient number of water-closets, latrines, privies, urinals and bathing or washing places for the separate use of each sex.

Power of President as to unhealthy privies.

34. Where the President is of opinion that any privy is likely to cause injury to the health of any person occupying the premises in which the privy is situated or occupying any adjacent premises, the President, with the previous approval of the Standing Committee, may, by written notice, require the owner of the premises in or on which such privy is situated to remove or so close up such privy as to prevent any person using the same, and to provide in lieu thereof such water-closet, latrine, privy, or urinal accommodation as the President may prescribe.

Use of places for bathing, or washing clothes or domestic utensils.

35. No person shall use or permit to be used as a bathing place, or as a place for washing clothes or domestic utensils, any part of any premises which has not been provided with all such appliances and fittings as shall, in the opinion of the President, be necessary for collecting the drainage thereof and conveying the same therefrom.

Public necessaries.

36. The President shall, so far as the means at his disposal permit, provide and maintain, in proper and convenient situations and on sites vesting in the Corporation, a sufficient number of water-closets, latrines, privies and urinals and other similar conveniences for public accommodation.

Section V.—Inspection.

Power of entry to inspect and examine drains, etc., not belonging to the Corporation.

37. All drains and other drainage works, such as ventilation-shafts and pipes, cesspools, filters or other treatment works, house-gullies, water-closets, privies, latrines and urinals, soil-pipes, waste-pipes, sinks, lavatories or other fittings and bathing and washing places which do not belong to the Corporation, or which have been constructed, erected or set up at the charge of the Municipal fund on premises not belonging to the Corporation, for the use or benefit of the owner or occupier of the said premises, shall be open to inspection and examination by the President, after 24 hours' written notice to the occupier at any time between 6 A. M. and 6 P. M, or if any business or trade is carried on at any time during which work is in progress.

Power to open ground, &c., for purpose of such inspection and examination.

38. For the purpose of such inspection and examination, the President may cause the ground or any portion of any drain or other drainage work, or with the approval of the Standing Committee, any portion of a building which he shall think fit to be opened, broken up or removed; provided that in the prosecution of any such inspection and examination as little damage as possible shall be done.

Wh n the expenses of inspection and ex mination are to be paid by the President.

39. If upon any such inspection and examination as aforesaid it shall be found that all the drains and other drainage works such as ventilation-shafts or pipes, cesspools, filters or other treatment works, house-gullies, water-closets, privies, latrines, urinals, soil-pipes, waste-pipes, sinks, lavatories or other fittings or bathing or washing places examined are in proper order and condition and that none of the provisions of this Act or of the Bye-laws in this behalf have been contravened in respect of the construction or maintenance thereof, the ground or portion of any building, drain or other drainage work, if any, opened, broken up or removed for the purpose of such inspection and examination shall be filled in, re-instated and made good by the President.

When the expenses of inspection and examination are to be paid by the owner.

40. But if it shall be found that any drain, or other drainage work such as a ventilation-shaft or pipe, cesspool, filter or other treatment work, house-gully, water-closet, privy, latrine, urinal, soil-pipe, waste-pipe, sink, lavatory or other fitting or bathing or washing place so examined is not in good order or condition and in accordance with the provisions of this Act and with the Bye-laws in this behalf, or has been constructed, repaired, or altered, except under the order of the President, the expenses of the inspection and examination shall be paid by the owner of the premises, and the said owner shall at his own cost fill in, re-instate and make good the ground, or portion of any building, drain or other work opened, broken up or removed for the purpose of such inspection and examination.

President may require repairs, &c., to be made.

41. (1) When the result of such inspection and examination as aforesaid proves that any of the provisions of this Division of the Act or the Bye-laws in this behalf have been contravened in any respect, the President may—

(*a*) by written notice require the owner of the premises or the several owners of the respective premises in which the drain, ventilation-shaft or pipe, cesspool, filter or other treatment work, house-gully, water-closet, privy, latrine, urinal, soil-pipe, waste-pipe, sink, lavatory or other fitting or bathing or washing place is situate, or for the benefit of which the same has been constructed, erected or set up,

(*i*) to close or remove the same or any encroachment thereupon, or

(*ii*) to renew, repair, alter or construct, cover, recover, trap, ventilate, pave and pitch or to do such other work with regard to the same as the President shall think fit to direct and to fill in, re-instate and make good the ground, building or thing opened, broken up or removed for the purpose of such inspection and examination, and

(*b*) without notice, close, fill up or demolish any drain by which sullage or sewage is carried through, from, into, under, or upon any premises, and the expenses incurred by the President in so doing shall be paid by such owner.

(2) Any requisition under sub-para. (*a*) of para. (1) in respect of any drain which has been constructed, erected or set up, or which is continued for the sole use and benefit of a property or for the exclusive use and benefit of

two or more properties, may include any extension thereof beyond such property or properties, if and so far as such extension has been constructed, erected or set up, or is continued, for the sole use and benefit of such property or properties.

Costs of inspection and execution of work in certain cases.

42. In the case of any drain which has been constructed, erected or fixed, or which is continued, for the exclusive use and benefit of two or more premises and which is not—

(*a*) a drain constructed under clause 14, para. (1), or

(*b*) a drain in respect of which conditions as to the respective responsibilities of the parties have been declared under clause 21, para. (1),

the expenses of any inspection and examination made by the President under clauses 37, 38 and 40, and of the execution of any work required under clause 41, whether executed under Section 46 or not, shall be paid by the owners of such premises, in such proportions as shall be determined—

(*i*) by the Standing Committee if the aggregate amount of such expenses exceeds one hundred rupees, or

(*ii*) by the President if the aggregate amount of such expenses does not exceed one hundred rupees.

Section VI.—General Provisions.

Prohibition of acts contravening the provisions of this division or done without sanction.

43. No person shall—

(*a*) in contravention of any of the provisions of this division or of any notice issued or direction given under this division, or without the written permission of the President, in any way alter the fixing, disposition or position of, or construct, erect, set up, renew, rebuild, remove, add to, obstruct, stop up, destroy, or change, any drain, ventilation-shaft or pipe, cesspool, water-closet, privy, latrine, urinal, soil-pipe, waste-pipe, sink, lavatory or other fitting or bathing or washing place or any trap, covering or other fitting or appliance connected therewith ;

(*b*) without the written permission of the President, use, renew, rebuild or unstop any drain, ventilation-shaft or pipe, cesspool, water-closet, privy, latrine, urinal, soil-pipe, waste-pipe, sink, lavatory or other fitting or bathing or washing place, or any fitting or appliance, which has been, or has been ordered to be, discontinued, demolished or stopped up under any of the provisions of this chapter.

Prohibition of passing injurious matters into drains.

44. No person shall—

(*a*) drop, pass or place, or cause or permit to be dropped, passed or placed, into or in any drain, any brick, stone, sand, earth, ashes, rags or any substance or matter by which or by reason of the amount of which the free flow in such drain may be interfered with or the drain itself injured ;

(*b*) pass, or permit or cause to be passed, into any drain provided for a particular purpose, any matter or liquid for the conveyance of which such drain has not been provided ;

(*c*) cause or suffer to be discharged into any drain from any factory, dyeing or bleaching work, chemical work, slaughter-house, gaswork, bake-house, distillery, workshop or workplace, or from any other building or place any liquid above 120° F., steam, chemical refuse, tar or pitch fumes or any liquid which would prejudicially affect the drain or the disposal by sale or otherwise of the sewage conveyed along the drain, or which would be likely to create a nuisance.

(2) To ensure compliance with para. (1) the owner shall take such means and construct, maintain and use such drains, filters, separators and other works as may be ordered by the President with the sanction of the Standing Committee. These means and works shall be subject to the provisions of Section V.

Conditions under which work may be done under this division, for any person by the President.

45. On the written request of any person who is required under any of the provisions of this division to do any work, the President may, in such person's behalf, cause the necessary work to be done; but he shall not do so in any case unless a deposit is first of all made by the said person of a sum which will, in the opinion of the President, suffice to cover the cost of the said work.

President may execute certain works under this division without allowing option to persons concerned of executing the same. Expenses in such cases by whom to be paid.

46. (1) The President may, if he thinks fit, cause any work described in this division to be executed by Municipal or other agency under his own orders, without first of all giving the person by whom the same would otherwise have to be executed the option of doing the same.

(2) The expenses of any work so done shall be paid by the person aforesaid, unless the Corporation shall, by a general or special order or Resolution, sanction the execution of such work at the charge of the Municipal fund.

CHAPTER XXI.

DRAINAGE BYELAWS.

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INTRODUCTION

Draft Byelaws now worked by P. W. D.

1. The byelaws submitted in this section have been drawn up on the assumption that the Corporation Act 1904 is amended as proposed in Chap. XX. By an agreement made with the Superintending Engineer to Government, 5th Circle, in April 1912, the Government, Public Works Department, agreed to execute their drainage work in Madras City in accordance with a draft series of byelaws similar to those now submitted. Enquiries from the Chief Engineer to Government have elicited the information that up to the present time nothing to object to has been discovered in these byelaws, but that Government have not yet had time to scrutinise them in that detail which is necessary before orders can be passed. The Chief Engineer to Government has, however, informed the writer demi-officially that Government would wish to employ their own contractors for carrying out the work and not be bound to employ only contractors licensed by the Corporation This appears quite reasonable and has been provided for in Byelaw 76.

The byelaws now submitted are very similar to those referred to above as having been sent to the Superintending Engineer, 5th Circle, in April 1912. They have been amended in some particulars which, in the writer's opinion, have improved them considerably in certain details. The draft byelaws, as well as the proposed clauses of the Act, have been submitted to the Corporation Health Officer and Engineer, who approved of them. The writer was fortunate in having Mr. Coats, the present Corporation Engineer, in his office at the time of preparing the byelaws. As soon as it was known that Mr. Coats was to be appointed Corporation Engineer, the writer requested him to go carefully through the byelaws, and he has made a number of valuable suggestions which have been adopted. The practical experience of Mr. Cartledge, the Corporation Drainage Superintendent, has been enlisted and has been of special value in framing the byelaws relating to sanitary fittings

Application to existing drainage.

2. It will be seen that the byelaws refer to persons "*by or for whom drainage work is carried out or altered.*" The byelaws do not refer to drainage existing at the time they come into force. If, however, insanitary conditions exist, in any case, the President may serve notice to have the drainage altered, and the drainage work after alteration will have to conform with the byelaws. Clause 74 provides that a drainage system constructed before the byelaws come into force, but not connected to the sewers, must be made to comply with the Byelaws so far as the President considers necessary, before a sewer connection will be made.

Byelaws refer only to work communicating with new drainage system.

3. The proposed byelaws refer only to work communicating with the new drainage system and no byelaws have been included respecting privies, except to state that these must not be connected to the system (*see* Byelaw 56). Proposed Clause 34 of the Act (*see* Chapter XX) gives the President

power to close privies and require water-closets to be substituted. Similarly, no byelaws have been proposed respecting horse and cattle stables, paving yards, and the like.

Building byelaws.

4. It would be advisable that drainage plans should be sanctioned before any building operations are put in hand. It would also be advisable that the present custom of raising the floors of the building above the road should be made compulsory, and, further, that the surfaces of all internal yards should be paved with impervious materials. These three points directly affect drainage, but it would appear that the regulations concerning them would be more appropriately placed under building byelaws. It is, therefore, recommended that the building byelaws should contain clauses somewhat as follows :—

(1) Before beginning to lay or dig the foundation of any new house or building, or to rebuild or reconstruct any house, building or drain, fifteen days' notice must be given to the President on a special form setting out full particulars of all drainage fittings, pipes, etc., as set out in the Drainage Byelaws.

(2) Ground floors of all houses to be raised not less than $1\frac{1}{2}$ feet above crown of road.

Note.—This is necessary to prevent flooding of houses during monsoon : it also facilitates drainage of houses, and is very generally adopted in Madras.

(3) The surface of all internal yards to be paved with impervious materials and to be finished at a level not lower than 6 inches below the floor level of the surrounding buildings.

Note.—This is required to prevent yard flooding of which numerous complaints are received by the writer during the monsoon.

Existing drainage byelaws.

5. Until quite recently there were no drainage byelaws, and owing to the considerable difficulty experienced in getting house drainage work carried out in a satisfactory manner, especially in connection with the essential exclusion of silt and rain-water, the writer suggested that certain of his draft byelaws, relating to notices and deposit of plans should be adopted. The Standing Committee of the Corporation carefully considered these and Government sanction was obtained to them with some slight modifications. These are printed in Appendix No. VII. in order that a comparison may be made with the corresponding clauses of the complete Byelaws now proposed.

Licensed contractors.

6. The differences are small. Perhaps the principal alteration is in the introduction of a clause providing that all drainage work shall be carried out by licensed contractors. Byelaw 66 provides that all drainage and other sanitary work, except that carried out by Corporation workmen, shall be executed only by licensed contractors. The license will specify the class of work the licensee is authorised to undertake and will be revoca[illegible] at any time at the absolute discretion of the President. A fee of Rs. 10 [illegible] to be paid before any license is granted. This is a clause on whic[illegible] The [illegible]om for differenc[illegible] of opinion. A similar clause was inserted by [illegible] [illegible]ation Comm[illegible]

appointed to consider the temporary drainage byelaws now in force, but it was subsequently decided to omit the clause. In the opinion of the writer, it is a valuable provision for both the Corporation and the owner, because it makes it to the interest of the contractor to do good work, otherwise he will lose his license.

In the case of open drains and channels, underground stoneware drains, manholes, etc., a license might be given to any first-class building contractor who applied for it, as he ought to be able to carry out such work satisfactorily, if he conforms with the byelaws, and such further instructions as may be issued by the drainage department of the Corporation. In the opinion of the writer, it is essential that plumbing work should be carried out only by licensed contractors. It would be quite impossible to get satisfactory work done by unlicensed men. The conditions under which a license would be granted are set out in Schedule B, page 237

Intercepting Trap.

7. Attention may be drawn to Byelaw 21 by which a disconnecting trap is not to be fixed between a house drainage system and the sewer, except where required by the Engineer. This is in accordance with a recent report of the English Local Government Board, where it is shown that a disconnecting trap is unnecessary—in fact undesirable—where the house drainage work is good. In the writer's opinion it may be omitted in the case of "first-class" drainage in Madras, with benefit to the community. The omission of the intercepting trap would undoubtedly greatly simplify the rather difficult problem of sewer ventilation.

In house drainage of the *second-class* type the intercepting trap is a necessity in order to exclude sewer gas from the house.

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Corporation of Madras.

DRAINAGE BYELAWS.

Byelaws made by the Corporation of Madras for regulating the dimensions, materials, form and mode of construction, and the maintaining, cleansing and repairing of the pipes and drains, communicating with the Municipal Drainage System and the traps and other apparatus connected therewith.

Note.—These byelaws have been drawn up on the assumption that the Corporation Act is amended as proposed in Chapter XX.

DRAINAGE BYELAWS.

I.—General Provisions.

Operation of byelaws.

1. These byelaws shall come into operation on the day of 19 , and shall remain in force until amended in accordance with the Madras City Municipal Act, 191 . Notice of such amendment being published in two or more newspapers circulating in the City of Madras.

Interpretation of terms and specification of materials.

2. In the construction of the byelaws with respect to drainage, the interpretation of terms given in Clause of the Madras City Municipal Act, 191 , shall apply throughout and the following words and expressions shall have the meanings hereinafter assigned to them unless such meanings be repugnant or inconsistent with the context, that is to say—

"*Portland Cement*" shall be of approved brand which complies with the British Standard Specification.

"*Cement Mortar*" shall consist of 1 part Portland Cement and 3 parts sharp clean sand measured by volume, thoroughly mixed with a proper proportion of water.

"*Brickwork*" shall be constructed of well burnt, hard, sound, truly shaped bricks laid in cement mortar and properly bonded.

"*Cement Concrete*" shall be composed of 1 part Portland Cement, 3 parts clean sharp sand and 6 parts clean hard broken stone or brick measured by volume, thoroughly mixed with a proper proportion of water.

Engineer to be judge of compliance with byelaws.

3. The Engineer shall be the sole judge of the sufficiency of the means taken to comply with any of these byelaws and of the suitability of the materials and quality of the workmanship employed. The Engineer shall have power to give in any case permission in writing allowing the use of materials other than those specified if he considers them to be equally suitable and efficient.

II.—Exclusion of Rain-water and Silt.

Every person by or for whom drains, sanitary fittings, or other works for new or existing buildings are laid out, constructed, fixed or altered shall comply with the following requirements :—

Separate drains to be provided for foul water and rain-water.

4. He shall make proper provision for the drainage of every building and premises, and shall deal with the rain and surface water separately from the sewage in every instance.

Rain-water drains.

5. He shall provide rain-water drains and shall divert all rain and surface water from roofs, court-yards and open spaces into them and away from any opening or inlet in connection with the foul water drain or any other drain leading to any Municipal drain or to any pumping station or any treatment

or disposal works, and he shall further provide and maintain such curbs, or other appliances as may be necessary to restrict all rain-water to the rain-water drains, which shall discharge freely at a point approved by the Engineer.

Rain-water pipes and gutters.

6. He shall provide all roofs of houses or other buildings with such efficient gutters of iron, zinc or other suitable material, and rain-water pipes of iron or zinc, as may be necessary to collect the rain-water and to discharge it into the drains or open channels constructed to receive such water. In no case shall he allow such rain-water pipes to discharge into any drain, trap or other work that communicates with the sewage system.

Inlets to drains to be above flood level.

7. He shall cause every inlet into any drain connected or proposed to be connected with the sewage system, to be made at least one foot above the level of the highest known flood at the site of such inlet. To this end he shall provide all gullies, and other openings communicating with the sewage system with masonry or other suitable curbs, of such height as will effectually prevent all rain or surface water gaining access to any drain communicating with the sewage system.

III.—Drainage of Buildings by Stoneware or Iron Pipes.

Every person by or for whom drains, sanitary fittings or other works for new or existing buildings are laid out, constructed, fixed or altered shall comply with the following requirements:—

Rain-water drains to be provided.

8. He shall provide in connection with such building, sufficient pipes, channels and gullies for the purpose of conveying to the drain provided for that purpose any water that may fall on the roof of that building.

He shall not cause any such pipes, channel or gullies to be so constructed as to receive any solid or liquid matter from any water-closet, urinal, slop or other sink, bath or lavatory.

If considered necessary by the Engineer any pipes shall be laid on, or surrounded with concrete as may be ordered by him.

Size of drain.

9. He shall cause every drain to be of adequate size; in no case shall it have an internal diameter of less than 4 inches, nor more than such size as may be necessary for the flow or as may be approved by the Engineer.

Gradients.

10. He shall cause every drain to be laid with a suitable fall approved by the Engineer. The standard gradient shall be 1 in 40 for 4-inch drains, and 1 in 80 for 6-inch drains, and it shall not be reduced or increased, except with the approval of the Engineer in writing.

Drains to be straight.

11. He shall cause every drain to be laid in straight lines and regular gradients with the fewest bends practicable and every change of direction to be formed by properly curved pipes or channels.

Junctions and bends to be formed in manholes.

12. He shall cause bends and junctions to be grouped together and wherever possible provide them with means of access by building manholes round them.

Materials.

13. He shall cause every drain, and every channel, manhole, or appliance with which sewage is likely to come into contact, to have smooth and rounded

surfaces, and to be made of impervious material (such as glazed stoneware, or cast-iron protected against corrosion by suitable preparation) or to be rendered with cement mortar.

14. If he shall construct any such drain of stoneware pipes, the thickness of the pipes and depths of the sockets and the annular space for the cement in proportion to the diameter shall be as follows:— **Pipes.**

Internal diameter.	Thickness of pipe not less than	Depth of socket not less than	Annular space for cement not less than
4 inches.	$\frac{1}{2}$ inch.	2 inches.	$\frac{3}{8}$ inch.
6 ,,	$\frac{5}{8}$,,	2 ,,	$\frac{1}{2}$,,
9 ,,	$\frac{3}{4}$,,	$2\frac{1}{2}$,,	$\frac{1}{2}$,,

The stoneware pipes shall be salt-glazed both inside and out and equal in every respect to the best English make.

They shall be truly cylindrical and straight, perfectly smooth and sound in all respects.

In the case of specials, they shall be perfect in shape, and if bends, shall be segments of a circle.

If he shall construct any such drain of cast-iron pipes, the thickness shall be at least $\frac{3}{8}$ inch for pipes up to 6 inches internal diameter. The weights per 9 feet length including socket shall not be less than 160 lbs. for 4-inch pipes and 230 lbs. for 6-inch pipes.

15. He shall cause all pipes to be provided with spigot and socket, flanged or collar joints, and to be of a pattern and quality approved by the Engineer. **Joints of drains.**

If he shall construct such drain of stoneware pipes, he shall cause such drain to be jointed with socket joints properly put together with a mixture of 1 part Portland Cement and two parts sand measured by volume.

If he shall construct such drain of cast-iron pipes jointed with socket joints, he shall cause such joints to be not less than $2\frac{1}{2}$ inches in depth and to be made with molten lead properly caulked and he shall also cause the annular space for the lead in the case of 4-inch pipes to be not less than $\frac{1}{4}$-inch in width and in the case of 6-inch pipes to be not less than $\frac{3}{8}$-inch in width.

He shall cause all excavations to be properly timbered where necessary for the protection of adjoining property. **Excavations.**

16. He shall cause every pipe to be securely bedded on firm ground, and filled round with selected material free from large stones, watered, and well rammed into place. Where any drain may traverse soft or yielding ground, or where water may make its appearance in the trench, he shall cause such drain to be bedded in or completely surrounded with at least four inches of good concrete, as may be directed, by the Engineer. **Bedding.**

17. He shall cause all pipes to be skilfully jointed either with suitable composition, tarred yarn and cement, or lead, and shall cause any projecting material or irregularity inside the drain to be carefully removed. **Jointing.**

Drains to be water-tight.

18. He shall cause every such drain to be so constructed as to be water-tight and shall test it in the presence of an authorised officer to a pressure of at least 4 feet head of water above the highest point of the drain. The drain to show no signs of leaking or oozing after the pressure has been maintained continuously for one hour and no pipe shall be covered up until it has passed this test to the satisfaction of the Engineer.

Traps to drain inlets.

19. He shall cause every inlet to a drain not being an inlet provided in pursuance of the byelaw in that behalf as an opening for the ventilation of such drain, to be properly trapped by an efficient trap so constructed as to be capable of maintaining a sufficient water seal of at least 2 inches. No trap of the kind known as a bell trap, a dip trap, or a D trap shall be constructed or fixed.

Traps and gullies.

20. He shall cause all gullies, traps, gratings, covers, or other appliances to be of a pattern, size and quality approved by the Engineer. He shall cause every stoneware gulley to be placed on a bed of concrete at least 4 inches thick, and set so that the water level therein is at least one foot, and the grating at least one inch below the surrounding pavement, and he shall cause the pavement to be sloped towards the gulley for a space equal to half the width of the grating.

Disconnecting trap.

21. He shall, when required by the Engineer but not otherwise, provide in every drain of such building which may immediately communicate with any sewer or Municipal drain, a suitable and efficient disconnecting trap at a point below the lowest inlet to such drain, and as near as may be practicable to the point at which such drain may be connected with the sewer.

He shall furnish adequate means of access for cleansing such trap by providing a manhole or other means of access approved by the Engineer.

Manholes, etc., to be water-tight.

22. He shall cause every means of access provided in compliance with any of the foregoing provisions of the byelaws to be constructed so as to be water-tight up to the level of the adjoining ground surface or road way and to be fitted with a suitable air-tight iron cover.

Drain junctions.

23. He shall not construct the several drains of such building communicating with a Municipal drain in such a manner as to form in such drains any right angled junction, either vertical or horizontal. He shall cause every such branch drain or tributary drain to join the main drain obliquely in the direction of the flow of such drain.

Drains under buildings.

24. He shall not construct any such drain so as to pass under any building, except where no other mode of construction may be practicable. If he shall construct such drain to pass under any building, then he shall cause such drain to comply with the following conditions :—

(*a*) The drain shall be laid in a straight line for the whole distance beneath the building.

(*b*) The drain shall be constructed either of cast-iron pipes, or of stoneware pipes completely surrounded with Portland cement concrete at least 6 inches thick.

(*c*) Adequate means of access shall be provided at each end of such portion of the drain as is beneath such building.

25. He shall in every case where a drain is laid through or beneath a wall, cause such drain to be protected at the laid through part beneath the wall by means of an arch, granite stone, reinforced concrete, or iron support which shall not bear on the drain and shall in the opinion of the Engineer be of sufficient size and strength to prevent any disturbance of or other injury to such drain. **Protection of pipes beneath walls.**

IV.—Ventilation of Drains.

Every person by or for whom drains, sanitary fittings or other works for new or existing buildings are laid out, constructed, fixed or altered shall comply with the following requirements :—

26. He shall provide an untrapped opening at the head of every drain or branch drains and at such other points as the Engineer may require. There shall be no trap or other obstruction to the free circulation of air between such ventilating openings. **Ventilating openings required.**

Each opening shall be obtained by carrying up vertically from the head of the drain a pipe or shaft which shall comply with the following conditions, namely, it shall :—

(*a*) not terminate within 20 feet distance from any window or opening into any building, nor below such window or opening ;

(*b*) if affixed to a wall supporting the eave of a roof, be carried up at least 2 feet higher than such eave ;

(*c*) be erected or affixed so as to create the least practicable nuisance or inconvenience to the inhabitants of the neighbourhood.

27. Where a disconnecting trap is required by the Engineer he shall, in addition to the requirements of the last preceding clause, provide an untrapped opening above and near the level of the surface of the ground adjoining such opening, and communicating with the drains by means of a suitable pipe, shaft or chamber, and situated as near as may be practicable to the disconnecting trap provided between the drain of the building and the Municipal drain. The point at which such opening communicates with the drain shall also in every case be situated on that side of the trap which is the nearer to the building. If in any case this arrangement is, in the opinion of the Engineer, undesirable, then the opening may be obtained by carrying up from the point referred to a suitable vertical pipe or shaft as specified in the last preceding clause. **Arrangements when disconnecting trap required.**

28. He shall cause every opening provided in accordance with any of the arrangements hereinbefore specified to be furnished with a suitable grating or other suitable cover for the purpose of preventing any obstruction in or injury to any pipe or drain by the introduction of any substance through any such opening. He shall, in every case, cause such grating or cover to be so constructed and fitted as to secure the free passage of air through such grating or cover by means of a sufficient number of apertures, of which the aggregate extent shall be not less than the sectional area of the pipe or drain to which such grating or cover may be fitted. **Openings to be protected.**

29. He shall not, except where unavoidable, cause any bend or angle to be made in any pipe or shaft used in connection with any of the arrangements hereinbefore specified. **No bends or angles in pipes.**

Diameter of pipes.

30. He shall cause every pipe or shaft which may be used in connection with any of the arrangements hereinbefore specified to have an internal diameter of not less than 4 inches, and to comply with British Standard Specification for cast-iron spigot and socket waste and ventilating pipes.

Soil pipes as ventilating pipes.

31. Provided always, that for the purpose of any of the arrangements hereinbefore specified the soil pipe of any water-closet, or the waste pipe of any slopsink constructed or adapted to be used for receiving any solid or liquid excremental filth, in every case where the situation, sectional area, height and mode of construction of such soil pipe or such waste pipe shall be in accordance with the requirements applicable to the pipe or shaft to be carried up from the drains, shall be deemed to provide the necessary opening for ventilation which would otherwise be obtained by means of such last-mentioned pipe or shaft.

V.—Waste Pipes.

Every person by or for whom drains, sanitary fittings, or other works for new or existing buildings are laid out, constructed, fixed or altered shall comply with the following requirements:—

Materials and sizes.

32. He shall cause every waste pipe from any bath, lavatory, sink or similar appliance (not being a slopsink or urinal constructed or adapted to be used for receiving any solid or liquid excremental filth) to be constructed of lead, or cast iron, $1\frac{1}{2}$ to 2 inches internal diameter and to be trapped immediately beneath such lavatory or sink by an efficient siphon trap, which shall be constructed of lead, iron, brass or stoneware with adequate means for inspection and cleansing, and which shall be ventilated into the external air whenever such ventilation may be necessary to preserve the seal of such trap. He shall not construct or fix in or in connection with such waste pipe, lavatory, or sink, any trap of the kind known as a bell trap, a dip trap or a D trap.

Traps.

If lead pipes are used they shall be of uniform thickness throughout and shall weigh at least $2\frac{3}{4}$ lbs. per lineal foot for $1\frac{1}{2}$-inch pipes, $3\frac{3}{4}$ lbs. per lineal foot for 2-inch pipes, and $5\frac{1}{2}$ lbs. per lineal foot for 3-inch pipes.

If cast-iron pipes are used they shall comply with the British Standard Specification for cast-iron spigot and socket waste and ventilating pipes.

To discharge into the air over a gulley.

33. He shall cause every such pipe in any building for carrying off waste water to be taken through an external wall of such building, by the shortest practicable line, and to discharge into the open air over a properly trapped gulley or over a channel leading to such gulley.

Supports.

34. He shall cause such waste pipe to be firmly attached to the walls in a manner satisfactory to the Engineer. If of cast iron properly fixed holder bats shall be used, provided always that it shall be sufficient if he shall secure the pipes to the walls in a manner considered by the Engineer to be equally suitable and efficient.

VI.—Water-closets, Latrines, Urinals, Slopsinks, and their proper Accessories.

Every person by or for whom drains, sanitary fittings or other works for new or existing buildings are laid out, constructed, fixed or altered shall comply with the following requirements:—

35. He shall cause every basin, urinal, slopsink, or receptacle constructed or adapted to be used for receiving any solid or liquid excremental filth, to be contained within a water-closet or latrine. He shall construct such water-closet or latrine in such a position that one of its sides at the least shall be an external wall. He shall not construct any such water-closet so that it is approached directly from any room used for the purpose of human habitation or used for the manufacture, preparation or storage of food for man, or used as a factory, workshop or work place, nor shall he construct any water-closet or latrine other than a flush-out, so that it can be entered otherwise than from the external air. **Position.**

36. He shall construct such water-closet or latrine which shall be at least 4 feet by 2 feet 9 inches internally, so that on any side on which it would abut on a room intended for human habitation, or used for the manufacture, preparation or storage of food for man, or used as a factory, workshop, or work place, it shall be enclosed by a solid wall or partition of brick or masonry extending the entire height from the floor to the ceiling. He shall provide any such water-closet or latrine with a floor of hard, smooth impervious material, having a fall of half-an-inch to a foot to the door where this opens on to the external air in the case of a raised receptacle or basin and to the basin where this is fixed flush with the floor. He shall cause the floor of all water-closets or latrines on the ground floor to be raised at least 6 inches above the ground outside. He shall provide such water-closet or latrine with proper doors and fastenings. **Construction.**

37. He shall construct in one of the external walls of such water-closet or latrine a window or opening at least 2 square feet in area, and with ventilating openings through an external wall of a total area of not less than 18 square inches near the floor, and 72 square inches as high up as practicable. **Lighting and ventilation.**

38. He shall furnish such water-closet or latrine with a cistern of the water waste preventing type of adequate capacity not less than $2\frac{1}{2}$ gallons and unless sanctioned by the Engineer not more than 3 gallons for the purpose of flushing, which shall be separate and distinct from any cistern used for drinking purposes and shall be so constructed, fitted and placed as to provide a head of at least 5 feet measured from the bottom of the cistern to the point of discharge of the flush pipe and to admit of the supply of water for use in such water-closet or latrine so that there shall not be any direct connection between any service pipe upon the premises and any part of the apparatus of such water-closet or latrine other than such flushing cistern. **Flushing cistern.**

He shall provide every such cistern with a suitable ballcock fixed on the supply pipe, and with an overflow pipe, discharging into the open air in some conspicuous position, but not over the inlet of any drain—*see* also Water-works Byelaws.

39. He shall not, except with the written permission of the President, construct or fix any self-acting or automatic flushing apparatus. In those cases, where the President's sanction is accorded, he shall submit for the approval of the Engineer detailed specifications and drawings to show the size of the apparatus, the materials of which it is to be made, and the mode and frequency of its operation, and shall modify the apparatus in any manner that may be required by the Engineer. **Automatic flushing apparatus.**

Flushing pipe.

40. He shall construct or fix the pipe and union connecting such flushing cistern with the pan, basin, or other receptacle with which such water-closet or latrine may be provided, so that such pipe and union shall not in any part have an internal diameter of less than $1\frac{1}{4}$ inch. The pipe shall be fixed as vertical as possible.

Water-closet receptacle, trap, and flushing arrangement.

*41. He shall furnish such water-closet or latrine with a suitable apparatus, a sample of which has previously been deposited with the Engineer and approved of by him in writing.

Such apparatus shall include—

(1) A suitable receptacle of such shape, capacity and mode of construction as

(*a*) to receive and contain a sufficient quantity of water,

(*b*) to allow all solid filth which may, from time to time, be deposited in such receptacle to fall free of the sides thereof and directly into the water contained in such receptacle, and so that the surface liable to fouling by urine shall be as small as possible,

(*c*) to be effectually flushed and cleansed by a small volume of water.

No receptacle shall be fixed which is of the "wash-out" type or has a "container" or other similar fitting.

(2) A suitable siphon trap directly connected to, and unless specially sanctioned in one piece with the said receptacle and so constructed as to maintain in the receptacle a sufficient quantity of water and to ensure a water seal of not less than 2 inches between such receptacle and any soil pipe or drain in connection therewith. Except where impracticable, the outlet of such siphon trap shall be made readily accessible.

(3) A suitable arrangement for the application of water to the receptacle in such a manner as to ensure the effectual flushing and cleansing of such receptacle, and the prompt and effectual removal therefrom and from the trap connected therewith of any solid or liquid filth which may from time to time be deposited therein.

No casing.

42. He shall not fix any casing of wood or other material round any receptacle, cistern or other apparatus of any water-closet.

VII.—Soil Pipes.

Every person by or for whom drains, sanitary fittings or other works for new or existing buildings are laid out, constructed, fixed or altered, shall comply with the following requirements:—

Position.

43. He shall whenever practicable cause every soil pipe provided for the purpose of conveying to a drain any solid or liquid excremental filth to be situated outside such building, and shall construct such soil pipe in drawn lead

* *Note.*—Type designs of latrines suitable for Madras have been prepared and may be inspected at the Municipal Office.

or of cast iron. Provided that in any case where it shall be necessary to construct such soil pipe within such building, he shall construct such soil pipe in drawn lead with joints in visible positions and so as to be easily accessible. If lead pipes are used they shall be solid drawn lead pipes at least 4 inches in diameter of uniform thickness throughout and shall weigh at least 7¼ lbs. per lineal foot for 4-inch pipes, 9¼ lbs. per lineal foot for 5-inch pipes, 11 lbs. per lineal foot for 6-inch pipes. If cast-iron pipes are used they shall comply with the British Standard Specification for cast-iron spigot and socket soil pipes.

Materials.

Thickness and weight.

44. He shall cause such soil pipe to be strongly supported at the foot upon a bed of concrete, and firmly attached to the walls. If the soil pipe is of cast iron then properly fixed holder bats shall be used. Provided always that it shall be sufficient if he shall secure the pipes to the walls in a manner considered by the Engineer to be equally suitable and efficient.

Supports.

45. He shall construct such soil pipe, whether inside or outside the building, so that it shall not be connected with any rain-water pipe or with the waste of any bath, or any sink other than that which is provided for the reception of urine or other excremental filth, and he shall construct such soil pipe so that there shall not be any trap in such soil pipe or between the soil pipe and any drain with which it is connected.

Connections.

46. He shall cause such soil pipe whether inside or outside the building to be circular and to have an internal diameter of not less than 4 inches and to be continued upwards without diminution of its diameter and (except where unavoidable) without any bend or angle being formed in such soil pipe, to such a height and in such a position as to afford by means of the open end of such soil pipe a safe outlet for foul air. The position of the open end being such as to comply with the conditions let out in Byelaws 26 (*a*), (*b*), (*c*).

Diameter.

Outlet.

VIII.—Soil Pipe, Waste Pipe and Ventilating Pipe Connnections.

Every person by or for whom drains, sanitary fittings or other works for new or existing buildings are laid out, constructed, fixed or altered, shall comply with the following requirements :—

47. In every case he shall cause lead pipes to be jointed with properly wiped plumber's joints, and shall cause cast-iron pipes to be jointed with molten lead properly caulked, the socket to be completely filled and the depth of lead after caulking to be not less than 1¾ inches.

Joints for lead and iron pipes.

Provided always that it shall be sufficient if he shall connect the pipes in a manner considered by the Engineer to be equally suitable and efficient.

48. He shall cause all soil pipes, waste pipes, ventilation pipes and all other pipes when above ground to be proved air-tight in presence of the Engineer or other authorised officer of the Corporation by smoke produced and applied as directed by the said Engineer or other authorised officer.

Pipes and joints to be air-tight.

Connection of lead pipe with cast-iron pipe.

49. In every case where he shall connect a lead soil pipe, waste pipe, ventilation pipe, or trap with a cast-iron pipe or drain, he shall insert between such lead pipe, or trap and such cast-iron pipe or drain, a flanged thimble of brass, copper or other suitable material and shall connect such lead pipe, or trap with such thimble by means of a wiped solder joint and shall connect such thimble with such cast-iron pipe or drain by means of a joint made with molten lead, properly caulked.

Provided always that it shall be sufficient if he shall connect the lead pipe or trap with the cast-iron pipe or drain in a manner considered by the Engineer to be equally suitable and efficient.

Connection of stoneware trap with lead pipe.

50. In every case where he shall connect a stoneware or semi-vitrifiedware trap or pipe, with a lead soil pipe, waste pipe, or trap he shall insert between such stoneware or semi-vitrifiedware trap or pipe and such lead pipe, or trap, a socket of brass, copper or other suitable material, and shall insert such stoneware or semi-vitrifiedware trap or pipe into such socket, making the joint with Portland cement mortar, and shall connect such socket with the lead pipe, or trap by means of a wiped solder joint.

Provided always that it shall be sufficient if he shall connect the stoneware or semi-vitrifiedware trap or pipe with the lead trap or pipe in a manner considered by the Engineer to be equally suitable and efficient.

Connection of lead pipe with stoneware drain.

51. In every case where he shall connect a lead soil pipe, waste pipe, ventilating pipe or trap with a stoneware or semi-vitrifiedware pipe or drain, he shall insert between such lead soil pipe, waste pipe, ventilating pipe or trap and such stoneware or semi-vitrifiedware pipe or drain a flanged thimble of copper, brass or other suitable alloy, and shall connect such lead pipe, or trap with such thimble by means of a wiped solder joint, and shall insert the flanged end of such thimble into a socket on such stoneware or semi-vitrifiedware pipe or drain making the joint with Portland Cement mortar.

Provided always that it shall be sufficient if he shall connect the lead pipe or trap with the stoneware or semi-vitrifiedware pipe in a manner considered by the Engineer to be equally suitable and efficient.

Connection of cast-iron pipe with stoneware drain.

52. In every case where he shall connect a cast-iron soil pipe, waste pipe, ventilating pipe, or trap with a stoneware or semi-vitrifiedware pipe, he shall insert the spigot end of such cast-iron pipe, or trap into a socket on such stoneware or semi-vitrifiedware pipe, making the joint with Portland cement mortar.

Provided always that it shall be sufficient if he shall connect the cast-iron pipe or trap with the stoneware or semi-vitrifiedware pipe in a manner considered by the Engineer to be equally suitable and efficient.

Connection of stoneware trap with cast-iron soil pipe.

53. In every case where he shall connect a stoneware or semi-vitrifiedware trap or pipe with a cast-iron soil pipe waste pipe, trap or drain, he shall insert such stoneware or semi-vitrifiedware trap or pipe into a socket on such cast-iron soil pipe, waste pipe, trap or drain, making the joint with Portland cement mortar.

For this purpose he shall provide the iron pipe with a specially large socket, so as to leave an annular space for the cement of not less than $\frac{5}{16}$ inch all round.

Provided always that it shall be sufficient if he shall connect the stoneware pipe or trap with the cast-iron pipe in a manner considered by the Engineer to be equally suitable and efficient.

IX.—Ventilation of Water-closet Traps.

Every person by or for whom drains, sanitary fittings, or other works for new or existing buildings are laid out, constructed, fixed or altered, shall comply with the following requirements :—

To be ventilated into the open air.

54. In every case where he shall construct any water-closet, the soil pipe of which is to be in connection with any other water-closet, he shall cause the trap of every such water-closet to be ventilated into the open air at a point as high as the top of the soil pipe, or into the soil pipe at a point above the highest water-closet connected with such soil pipe, and so that the ventilating pipe shall have in all parts an internal diameter of not less than 2 inches and shall be connected with the arm of the soil pipe, or the trap at a point not less than 3 inches and not more than 12 inches from the highest part of the trap and on that side of the water seal which is nearest to the soil pipe. He shall cause the joint between the ventilating pipe and the arm of the soil pipe or the trap to be made in the direction of the flow.

Materials and supports.

55. He shall construct such ventilating pipe in drawn lead or heavy cast iron, as specified for waste pipes in Byelaw 32, and supported in the manner set out in Byelaw 34.

Provided that in any case where it shall be necessary to construct such ventilating pipe within a building he shall construct such ventilating pipe in drawn lead.

X.—Drainage of Privies, Ashpits, etc.

Washings only to be conveyed to drain.

56. Every person by or for whom drains are constructed shall not allow any privy, earth-closet, ash-pit, or receptacle for filth to be connected directly or indirectly with the drains. He shall cause the washings from the floor of any such place to be carried by a open channel, properly curbed to exclude silt and storm water, outside such place, leading to a trapped gulley provided with a "Madras" type silt-catcher.

XI.—Open Drains.

Every person by or for whom drains or other works communicating with the Municipal Drainage system are constructed, fixed or altered, shall comply with the following requirements :—

Construction.

57. He shall cause all open drains or surface channels to be constructed with half-round glazed stoneware, socketted channels for the inverts laid on a bed of fine Portland cement concrete extending in depth from the top of the channel to at least 3 inches below the underside thereof, and in width at least 3 inches on both sides of the channel Above the channel, the drain may be constructed of brickwork in Portland ement mortar plastered with at least $\frac{1}{2}$ inch of cement mortar. He shall construct no drain less than 4 inches deep and 4 inches

wide. He shall provide curbs to all such drains or channels at least 4 inches above the adjoining ground surface or of such greater height as will effectually prevent all rain or surface water gaining access to the drains.

Provided always that it shall be sufficient if he shall construct such drains or channels in a manner and with materials considered by the Engineer to be equally suitable and efficient.

Grating.

58. He shall cause to be fixed at each outlet of every foul water drain a cast-iron grating of a design approved by the Engineer. He shall also provide a cast-iron pipe at least 4 inches in diameter and $\frac{1}{4}$ inch in thickness leading from such outlet and of sufficient length to be fixed to the trap provided in compliance with the following byelaw.

Silt-catcher and trap.

*59. He shall provide to each outlet of every such drain an efficient trap and silt-catcher of the "Madras" type of a design approved by the Engineer, such trap and silt-catcher to be fixed in a manner and position also approved by the Engineer.

XII.—Maintenance of Drainage System.

Drainage work and appliances to be maintained in proper repair.

60. The owner of any premises shall at all times maintain in a proper state of repair all pipes, drains, traps and other works, appliances and apparatus connected with the drainage of the premises, and shall give any duly authorised officer of the Corporation every facility to inspect the same.

XIII.—Notices and Deposit of Plans.

Notice of intention to construct works.

61. Every person who intends or is required to lay out, construct, or alter any drains, sanitary fittings or other drainage works shall before commencing any such work give the President fifteen days' notice in writing of such intention, and such notice, in duplicate, shall be delivered at the Municipal Office in the form (*See* Schedule A page 228), of which printed copies with the necessary blanks may be obtained by application at the Municipal Office on payment of two annas per copy.

He shall enter upon such notice his full name and address, and shall state the division, street and assessment number of the premises upon which such works are intended to be executed, and all the particulars required in the printed form of notice.

Deposit of plans and sections.

62. Every person who intends or is required to lay out, construct, or alter any drains, sanitary fittings or other drainage works shall deposit, together with such notice, plans and sections in duplicate clearly and indelibly made on a durable material and drawn to a scale of not less than one inch to every 16 feet, and the horizontal scale of the sections shall be the same as the scale of the plans, and he shall show thereon the whole of the intended new drains with their proposed sizes and gradients in figures, and the levels of the ground surface and depths of the proposed drains, and the position of every building, gulley, soil pipe, waste pipe, ventilating pipe, water-closet, bath, lavatory, urinal, latrine, sink, trap, or other appliance on the premises connected or proposed to be connected with any drains, and the position and course of all surface drains and the names of the

* *Note.*—Clause 59 will require modifying in accordance with the final decision as to what proportion of the house connection shall be paid for by the owner.

streets adjoining the premises, and the scale to which the plan is drawn ; and the proposed new drains and appliances shall be shown in red, and the existing buildings, drains and appliances in black, or otherwise distinctively indicated by different colours.

He shall also deposit cross sections (with dimensions shown in figures) to a scale of not less than one inch to one foot, of all open drains showing the ground level and the curbs or other means, already existing or proposed, for exclusion of storm water and silt.

On application by any party the Corporation will provide him with the necessary plans and estimates on payment of a sum equal to 5 per cent. of the estimates subject to a minimum charge to be fixed from time to time by the Standing Committee Such application shall be accompanied by a deposit of two rupees which will be credited to the abovementioned charge for plans and estimates.

Approval or disapproval of plans.

63. Within thirty days after the deposit of the notice and plans and sections required by the last preceding byelaw, the President shall signify in writing to the person who gave such notice whether such plans and sections are approved or otherwise, and may direct such person to make any alterations or improvements which appear to be necessary or desirable, and such person shall alter the plans and sections accordingly.

When the plans and sections have been approved, one copy thereof shall be returned to such person and one copy shall be retained by the President One copy of the plans and sections approved by the President shall be kept at the site of the work at all times when the work is in progress and such plans and sections shall be available at all times for the inspection of the President or of any officer authorised by him in that behalf.

Commencement of work.

64. Such person may then proceed with the work, excepting such portions thereof as may be reserved by the President for final connection with any drain vested in the Corporation ; provided that, if the work is not commenced within three months from the date of the notice of approval of such plans, such approval shall be deemed to be cancelled.

Unlawful commencement of work.

65. Every person who, without first obtaining the consent of the President in writing, commences any such work before the plans and sections have been approved shall be liable to a penalty, as specified in Byelaw 72.

License to carry out private drainage.

66. Every contractor or other person, excepting the duly authorised officers of the Corporation, shall, before carrying out any works connected with the construction, fixing, and alteration of private drains and drainage appliances, first obtain a license signed by the President. Such license shall specify the period for which it shall remain in force and the class of work the licensee is authorised to undertake, and shall be revocable at any time at the absolute discretion of the President, and a fee of ten rupees shall be paid before any license shall be granted.

No plumbing work shall be executed except, by a person whose name is at the time included in the Corporation list of authorised plumbers. (*See* Schedule B, attached).

Notice of covering up portions of works.

67. Every person who constructs or alters any drains or other drainage works shall, before proceeding to cover up any portion of any foundations, drains, or appliances, connected with drainage, give the Engineer notice in writing that such foundations, drains, or appliances are ready for inspection, and specify the date and hour on which he will proceed to cover up such foundations, drains, or appliances, and such notice shall be in a form of which printed copies with the necessary blanks may be obtained gratis on application at the Municipal Office, and he shall cause such notice to be delivered at the Municipal Office at least three clear days before the date specified therein.

Notice of completion.

68. Every person who constructs or alters any drains or other drainage works shall give the Engineer notice in writing specifying the date and hour at which such drains or works will be ready for final inspection, and, if required, for connection with any existing drain, and such notice shall be in a form, of which printed copies with the necessary blanks may be obtained by payment of one anna on application at the Municipal Office, and he shall cause such notice to be delivered at the Municipal Office at least seven clear days before the date specified as aforesaid therein.

Connection with Municipal drain.

69. No connection of any drain to any Municipal drain shall be made until a certificate has been issued by the Engineer that the whole of the first-mentioned drain and the appliances connected therewith comply with all requirements of the Corporation. Such connection shall in any case be made only by duly authorised officers of the Corporation, after receipt by the President of a written application accompanied by a copy of the said certificate.

Deposit of money.

70. Every person who applies for a connection to a Municipal drain shall deposit such sum of money as the President may demand to meet the cost of the connection before such connection is commenced.

Inspection.

71. Every person by or for whom any drain or other work connected therewith is laid out, constructed, fixed, or altered shall at all reasonable times afford any authorised officer of the Corporation free access to such drain or work for the purpose of inspection.

XIV.—Penalties.

Penalties.

72. Every person who shall offend against any of the foregoing byelaws shall be liable for every such offence to a penalty not exceeding fifty rupees, and in case of a continuing offence to a further penalty not exceeding ten rupees for each day after written notice from the President to discontinue the offence shall have been duly served upon or delivered to such person.

XV.—Power to pull down work.

Power to remove, alter or pull down work.

73. If any work be begun or done in contravention of the foregoing byelaws, the person by or for whom such work was so begun or done, by a notice in writing signed by the President and duly served upon or delivered to such person, shall be required, on or before such day as shall be specified in such notice by a statement in writing under his hand or the hand of an agent authorised in that behalf and addressed to and duly served upon the President, to show

sufficient cause why such work shall not be removed, altered, or pulled down; or shall be required on such day and at such time and place specified in such notice to attend personally or by an agent authorised in that behalf before the President and show sufficient cause why such work shall not be removed, altered, or pulled down.

If such person fail to show sufficient cause why such work shall not be removed, altered, or pulled down, the President shall be empowered to remove, alter or pull down such work, and to recover the cost of so doing from such person.

XVI.—Application of Byelaws to existing Drainage Systems.

Extent of compliance with bye-laws.

74. Every person who shall connect to the sewers a house drainage system constructed before the confirmation of these byelaws shall first cause the said house drainage system to comply with these byelaws so far as the President considers necessary.

XVII.—Drainage Works carried out by Government in the City of Madras.

Plans, estimates and descriptions to be submitted.

75. As soon as any sanitary works are sanctioned, Government will send to the President, Corporation of Madras, notice of the works proposed.

Plans and estimates of sanitary works shall be drawn up in accordance with the byelaws of the Corporation of Madras. The Sanitary Board's Certificate that these byelaws have been complied with shall be accepted by the President.

Blue prints and descriptions of the works on the application form, as specified in the byelaws, will be lodged with the President for record.

Information as to the quantity of water required and the sewage to be disposed of will also be supplied to the President at the same time as the application is submitted.

Government to carry out work by any agency they may select.

76. As soon as the particulars above specified have been lodged with the President, Government shall be at liberty immediately to proceed with the execution of the work by such agency as they may select, not necessarily a contractor licensed by the Corporation. On condition that any alteration that may be proposed by the President within 14 days of receipt by him of the particulars shall immediately be considered, and if there is any difference of opinion, the matter shall at once be submitted to the Sanitary Board.

Note.—The above regulations are in close agreement with those drawn up by the writer and the Superintending Engineer to Government, 5th Circle, in April 1912. They appear reasonable both from the point of view of the Corporation who wish their byelaws to be observed in all works carried out in the city by Government and also from the point of view of Government whose sanitary experts should not require supervision in the same way as would a contractor working for private parties.

The regulations were drafted with reference to the Water-supply and Drainage Byelaws prepared by the writer, but might be adopted, with some slight modification to building and other byelaws if considered desirable.

SCHEDULE A.

TO BE SUBMITTED IN DUPLICATE.

Drainage Register No...... *Application No.*.....

Received
Approved

The Corporation of Madras.

THE MADRAS MUNICIPAL ACT, 191 .

DRAINAGE OF PREMISES.

To

THE PRESIDENT,
CORPORATION OF MADRAS.

SIR,

$\frac{\text{I}}{\text{We}}$, the undersigned, hereby give you notice of $\frac{\text{my}}{\text{our}}$ intention to drain the premises known as*.....

.....

in the Division, as described in the appended details and as shown on the accompanying plans and sections (submitted in duplicate), and undertake to pay to the Corporation the cost of so much of the connection to the Municipal Drainage System as is required by the provisions of the above mentioned Act and the Bye-laws made thereunder by the Corporation of Madras, and to carry out the remainder of the works in accordance with the provisions of the said Acts and Bye-laws.

Dated this..... *day of*..... 191 .

Signature of person intending to drain the premises......

Address.....

.....

Name of the owner of the house.....

Address.....

.....

† NOTE.—It is laid down in the Bye-laws of the Corporation that before beginning to lay or dig out the foundation of any new house or building, or to re-build any house or building, and also before making or reconstructing any drain for the purpose of draining directly or indirectly, into any Municipal drink notice is to be given to the President, on forms to be obtained from the Municipal Office, such notice to be accompanied by PLANS and SECTIONS in DUPLICATE, showing the position, depth, inclination and size of the proposed drain and all connections therewith, in accordance with the Bye-laws made by the Corporation.

* Insert the number or name of the house, and the name of the street or road.

† This should form part of the new Building Bye-laws.—

EXTRACT FROM BYE-LAWS

(MADE BY THE CORPORATION OF MADRAS).

UNDER THE MADRAS MUNICIPAL ACT, 191 .

Relating to Notices and Deposit of Plans.

XIII.—Notices and Deposit of Plans.

Notice of intention to construct works.

61. Every person who intends or is required to lay out, construct, or alter any drains, sanitary fittings or other drainage works shall before commencing any such work give the President fifteen days' notice in writing of such intention, and such notice, in duplicate, shall be delivered at the Municipal Office in the form (*See* Schedule A page 226), of which printed copies with the necessary blanks may be obtained by application at the Municipal Office on payment of two annas per copy.

He shall enter upon such notice his full name and address, and shall state the division, street and assessment number of the premises upon which such works are intended to be executed, and all the particulars required in the printed form of notice.

Deposit of plans and sect

62. Every person who intends or is required to lay out, construct, or alter any drains, sanitary fittings or other drainage works shall deposit, together with such notice, plans and sections in duplicate clearly and indelibly made on a durable material and drawn to a scale of not less than one inch to every 16 feet, and the horizontal scale of the sections shall be the same as the scale of the plans, and he shall show thereon the whole of the intended new drains with their proposed sizes and gradients in figures, and the levels of the ground surface and depths of the proposed drains, and the position of every building, gulley soil pipe, waste pipe, ventilating pipe, water-closet, bath, lavatory, urinal, latrine, sink, trap, or other appliance on the premises connected or proposed to be connected with any drains, and the position and course of all surface drains and the names of the streets adjoining the premises, and the scale to which the plan is drawn ; and the proposed new drains and appliances shall be shown in red, and the existing buildings, drains and appliances in black, or otherwise distinctively indicated by different colours.

He shall also deposit cross sections (with dimensions shown in figures) to a scale of not less than one inch to one foot, of all open drains showing the ground level and the curbs or other means, already existing or proposed, for exclusion of storm water and silt.

On application by any party the Corporation will provide him with the necessary plans and estimates on payment of a sum equal to 5 per cent. of the estimates subject to a minimum charge to be fixed from time to time by the Standing Committee. Such application shall be accompanied by a deposit of two rupees which will be credited to the abovementioned charge for plans and estimates.

Approval or disapproval of plans.

63. Within thirty days after the deposit of the notice and plans and sections required by the last preceding byelaw, the President shall signify in writing to the person who gave such notice whether such plans and sections are approved or otherwise, and may direct such person to make any alterations or improvements which appear to be necessary or desirable, and such person shall alter the plans and sections accordingly.

When the plans and sections have been approved, one copy thereof shall be returned to such person and one copy shall be retained by the President. One copy of the plans and sections approved by the President shall be kept at the site of the work at all times when the work is in progress and such plans and sections shall be available at all times for the inspection of the President or of any officer authorised by him in that behalf.

Commencement of work.

64. Such person may then proceed with the work, excepting such portions thereof as may be reserved by the President for final connection with any drain vested in the Corporation; provided that, if the work is not commenced within three months from the date of the notice of approval of such plans, such approval shall be deemed to be cancelled.

Unlawful commencement of work.

65. Every person who, without first obtaining the consent of the President in writing, commences any such work before the plans and sections have been approved shall be liable to a penalty, as specified in Byelaw 72.

License to carry out private drainage.

66. Every contractor or other person, excepting the duly authorised officers of the Corporation, shall, before carrying out any works connected with the construction, fixing, and alteration of private drains and drainage appliances, first obtain a license signed by the President. Such license shall specify the period for which it shall remain in force and the class of work the licensee is authorised to undertake, and shall be revocable at any time at the absolute discretion of the President, and a fee of ten rupees shall be paid before any license shall be granted.

No plumbing work shall be executed except, by a person whose name is at the time included in the Corporation list of authorised plumbers. (*See* Schedule B, attached).

Notice of covering up portions of works.

67. Every person who constructs or alters any drains or other drainage works shall, before proceeding to cover up any portion of any foundations, drains, or appliances, connected with drainage, give the Engineer notice in writing that such foundations, drains, or appliances are ready for inspection, and specify the date and hour on which he will proceed to cover up such foundations, drains, or appliances, and such notice shall be in a form of which printed copies with the necessary blanks may be obtained gratis on application at the Municipal Office, and he shall cause such notice to be delivered at the Municipal Office at least three clear days before the date specified therein.

Notice of completion.

68. Every person who constructs or alters any drains or other drainage works shall give the Engineer notice in writing specifying the date and hour at which such drains or works will be ready for final inspection, and, if required, for connection with any existing drain, and such notice shall be in a form, of which printed copies with the necessary blanks may be obtained by payment of one anna on application at the Municipal Office, and he shall cause such notice

to be delivered at the Municipal Office at least seven clear days before the date specified as aforesaid therein.

Connection with Municipal drain.

69. No connection of any drain to any Municipal drain shall be made until a certificate has been issued by the Engineer that the whole of the first-mentioned drain and the appliances connected therewith comply with all requirements of the Corporation. Such connection shall in any case be made only by duly authorised officers of the Corporation, after receipt by the President of a written application accompanied by a copy of the said certificate.

Deposit of money.

70. Every person who applies for a connection to a Municipal drain shall deposit such sum of money as the President may demand to meet the cost of the connection before such connection is commenced.

Inspection.

71. Every person by or for whom any drain or other work connected therewith is laid out, constructed, fixed, or altered shall at all reasonable times afford any authorised officer of the Corporation free access to such drain or work for the purpose of inspection.

XIV.—Penalties.

Penalties.

72. Every person who shall offend against any of the foregoing byelaws shall be liable for every such offence to a penalty not exceeding fifty rupees, and in case of a continuing offence to a further penalty not exceeding ten rupees for each day after written notice from the President to discontinue the offence shall have been duly served upon or delivered to such person.

DETAILED DESCRIPTION OF WORK AND SPECIFICATION OF MATERIALS.

(TO BE FILLED IN BY APPLICANT OR PERSON DEPOSITING PLANS).

N.B.—Only new or altered work to be described in the following particulars :—

Copies of Bye-laws relating to Drainage Work may be obtained at the Municipal Office on payment of four annas each.

1. Separation of rain-water and foul water. See Bye-law No. 4, etc.	
2. Rain-water drains, curbs, and point of discharge ... ... See Bye-laws Nos. 5 and 8, etc. ...	
3. Rain-water gutters, pipes or spouts, where discharging ... ... See Bye-law No. 6, etc.	
4. Open foul water drains, their materials, sizes, curbs and other means taken to exclude silt and rain-water. Number of washing places, verandahs, latrines and fittings discharging into such drains ... ... See Bye-laws Nos. 4 and 57, etc. ...	
5. Silt-catcher and grating size and position ... ... See Bye-laws Nos. 58 and 59 ...	
6. Drains— (*a*) Main Sewage Drain—size ... —fall ... (*b*) Branch Drains —size ... —fall ... (*c*) Materials ... ... (*d*) Method of jointing ... ... See Bye-laws Nos. 8 to 15 and 17, etc...	

7. Bedding of pipes—	
(*a*) Method of bedding	
(*b*) Thickness and width of beds of concrete	
(*c*) Thickness of concrete round pipes.	
See Bye-law No. 16, etc.	
8. Protection of drain laid under wall.	
See Bye-law No. 25, etc. ...	
9. Traps, Description of—	
Interceptor	
Lavatory waste pipes	
Bath do.	
Sink	
Gully traps	
Water-closet traps	
Grease traps	
Slop sink	
Urinal	
Others	
See Bye-laws Nos. 19, 20, 21, 32, 33, 41, 59, etc.	
10. Manholes and Inspection Chambers ...	
Thickness of walls	
Description of bricks	
Do. rendering ...	
Do. invert channels ...	
Depth of chambers	
Size and description of cover and manner of fixing	
See Bye-laws Nos. 12, 22, etc. ...	

11. Ventilation of Drains—	
(*a*) Fresh Air Inlet—	
Position...	
Height above nearest ground level	
(*b*) Outlet Shaft—Position ...	
Terminal at top	
See Bye-laws Nos. 26 to 31. ...	
12. Soil Pipe, Waste Pipe and Ventilating Pipe Connections—	
(*a*) Lead and iron pipes (Bye-law No. 47, etc.)	
(*b*) Lead pipe, or trap with cast-iron pipe	
See Bye-law No. 49, etc.	
(*c*) Stoneware pipe or trap with lead pipe	
See Bye-law No. 50, etc.	
(*d*) Lead soil pipe or trap with stoneware pipe or trap ...	
See Bye-law No. 51, etc.	
(*e*) Cast-iron pipe with stoneware drain	
See Bye-law No. 52, etc.	
(*f*) Stoneware trap with cast-iron soil pipe	
See Bye-law No. 53, etc.	
13. Ventilation of Water-closet Trap ...	
Materials and supports	
See Bye-laws Nos. 54 and 55, etc. ...	

14. Water-closets (Apartments)—	
(*a*) At or above ground level—	
Approached from ...	
Floor material	
Do. fall towards door ...	
See Bye-law Nos. 35 and 36, etc. ...	
Size of window made to open.	
Position of same	
Means of constant ventilation ...	
Position of same	
See Bye-law No. 37, etc.	
(*b*) Water-closet Apparatus—	
Description of pan, basin, &c.	
Flushing cistern { Kind ... / Capacity...	
Flush pipe	
Material	
Internal diameter ...	
Union with basin ...	
See Bye-laws Nos. 38 to 42 ...	
17. Other Work—	
Description of any other sanitary work to be carried out not included under above headings.	
18. Depth of sewer below surface of street.	

SCHEDULE OF PIPES.

	Materials.	Diameter.	Weight.	Method of Jointing.
Sub-soil Drains				
Main Sewage Drains				
Branch Sewage Drains ...				
Soil Pipes				
Ventilating Pipes other than Soil Pipes				
Waste Pipes				
Rain-water Pipes				
Anti-siphon Pipes				

(Signed).....

.....191 .

SCHEDULE B.

Authorisation of Plumbers.

Any authorised list of plumbers issued by the President shall include the names and addresses of all plumbers who shall make application to the President on the form provided for this purpose, and who shall either :—

(1) produce a certificate of registration from the Worshipful Company of Plumbers of Great Britain under the conditions appertaining to the National Registration of Plumbers, or from such other body as may be set up by Statute or be approved by the Local Government, and upon such terms as the Government shall sanction ; or

(2) satisfy the President of their competence to carry out plumbing work in accordance with the Regulations of the Corporation.

Provided always that the President may at his discretion refuse to grant a certificate to any applicant without giving any reason for his action in this respect.

Any plumber applying for a certificate may be required to pass a theoretical and practical examination before a certificate is granted. Master plumbers shall only employ certificated plumbers to do plumbing work.

Every plumber applying for a license shall deposit with the President the sum of Rs. 200 as a security for the due and proper fulfilment of a plumber's duties. He will then be licensed annually after signing an agreement, and paying a fee of Rs. 10 within the first month of each official year.

In the event of the President having cause for complaint against any plumber, whose name is included on the Authorised List, for doing unsatisfactory work or for contravening the Regulations of the Corporation, and, failing to receive reasonable or sufficient explanation or excuse for such contravention of the Regulations, the President shall be entitled to summarily cancel the name of such defaulting plumber from the Authorised List. In such event the President may retain the whole or any part of the Rs. 200 deposited as security.

APPENDIX No. 1.

STATEMENT OF LENGTHS IN FEET OF PIPE SEWERS ABOVE AND BELOW SUBSOIL WATER LEVEL.

Appendix

Statement of Lengths in Feet of Pipe Sewers

DRAINAGE AREA.	STONEWARE PIPE							
	6 inches diameter.		9 inches diameter.		12 inches diameter.		15 inches diameter.	
	Above.	Below.	Above.	Below.	Above.	Below.	Above.	Below.
Mylapore	29,195	100	43,456	2,704	4,707	2,863	1,200	5,510
Edward Elliott's Road ...	24,661	56	14,814	8,771	2,995	3,073	...	2,065
Ice House Road	44,470	...	42,904	3,656	3,080	1,830	530	770
Napier Park	59,723	242	24,195	1,945	1,908	1,932	345	2,525
Graeme's Road	39,389	...	35,894	1,500	4,784	2,440	1,276	4,937
Lang's Gardens	21,793	92	19,587	2,126	3,418	2,731	...	1,185
Purasawakkum	97,884	1,886	64,382	18,438	6,626	7,264	3,563	7,517
Law College	40,181	114	35,221	1,317	2,141	499	...	930
Rayapuram	95,702	6,501	72,203	4,511	4,636	2,484	1,040	200
Totals ...	452,998	8,991	352,656	44,968	34,295	25,116	7,954	25,639
Tondiarpet (North) ...	29,710	...	32,065	3,995	6,885	3,425	402	7,038

No. 1.

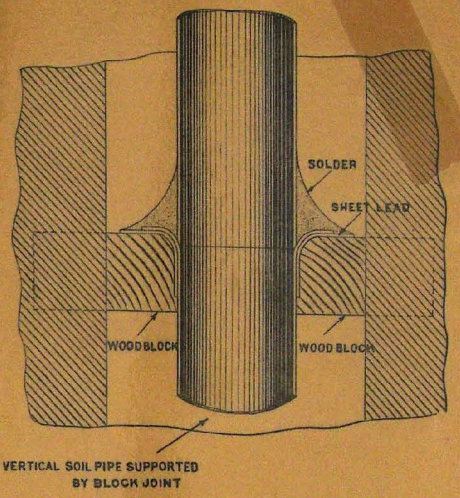
Above and Below Subsoil Water Level.

Sewers.				Cast-iron Pipe Sewers.							
18 inches diameter.		21 inches diameter.		24 inches diameter.		27 inches diameter.		30 inches diameter.		36 inches diameter.	
Above.	Below.	Above.	Below.	Above.	Below.	Above.	Below.	Above.	Below.	Above.	Below.
...	1,940	...	...	...	...	...	...	...	...	...	...
...	1,670	1,176	5,337	...	...	...	...	...	...	...	...
400	...		1,530	...	840	...	1,280	...	970	...	...
1,230	3,190	...	1,675	...	1,890	...	...	...	1,890	...	...
...	1,910	...	650	...	...	...	...	...	...	...	...
70	330	980	2,380	...	1,600	...	...	...	...	...	...
1,260	4,990	...	2,590	...	...	...	...	...	...	...	...
...	460	386	2,869	...	...	...	...	...	140	...	...
862	442	...	1,830	...	1,980	...	1,520	...	1,160	...	3,880
3,822	14,932	2,542	18,861	...	6,390	...	2,800	...	4,160	...	3,880
2,980	...	...	...	...	...	...	...	...	...	...	...

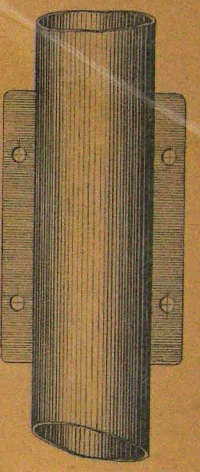
FIRST-CLASS HOUSE DRAINAGE.
DETAILS.

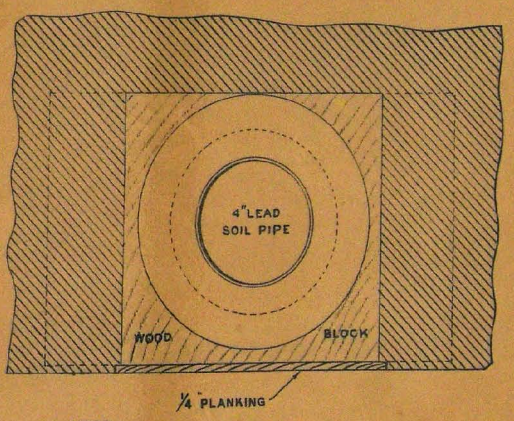
PLATE XXIX.

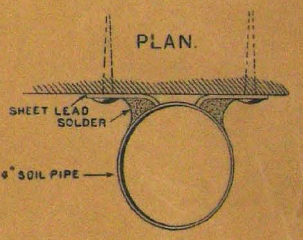
SECTIONAL ELEVATION OF BLOCK-JOINT FOR USE ON LEAD SOIL PIPE FIXED INSIDE PREMISES



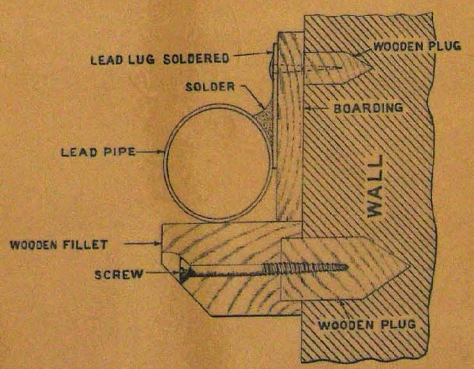
PLAN AND ELEVATION SHOWING METHOD OF FIXING LEAD SOIL PIPE TO WALL





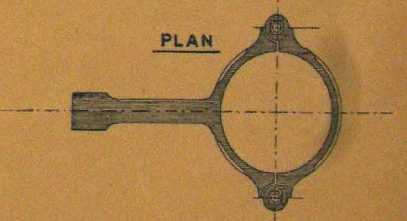


NOTE:- LEAD PIPE EITHER HORIZONTAL OR INCLINED, MUST BE SUPPORTED ON WOODEN FILLET

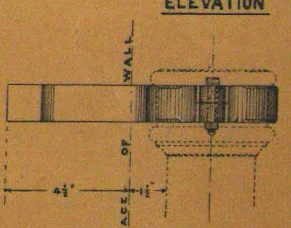


HOLDER BAT

PLAN



ELEVATION



J. W. Madeley.

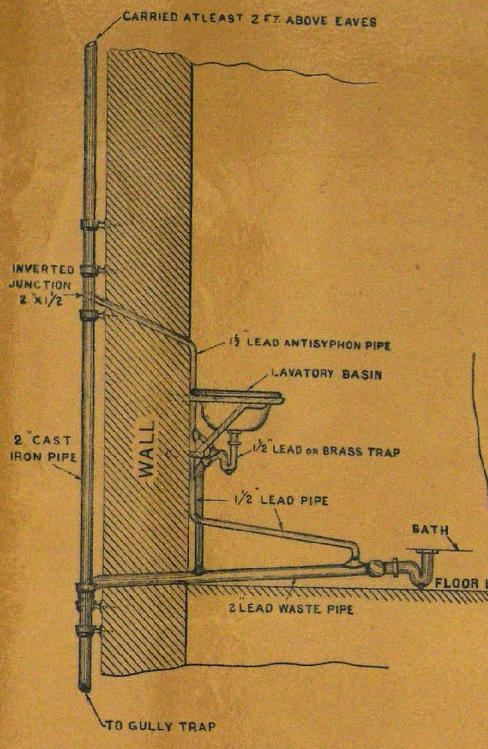
M.A., M. Inst. C. E., M. Am. Soc. C.E., Etc.,
Special Engineer,
Corporation of Madras.

PLATE XXX.

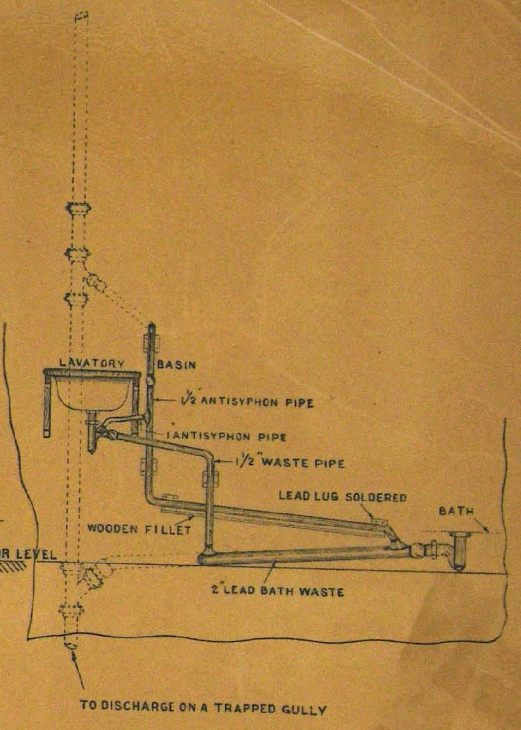
FIRST-CLASS HOUSE DRAINAGE.

BATH AND LAVATORY WASTE WITH VENT PIPE ON 1ST FLOOR

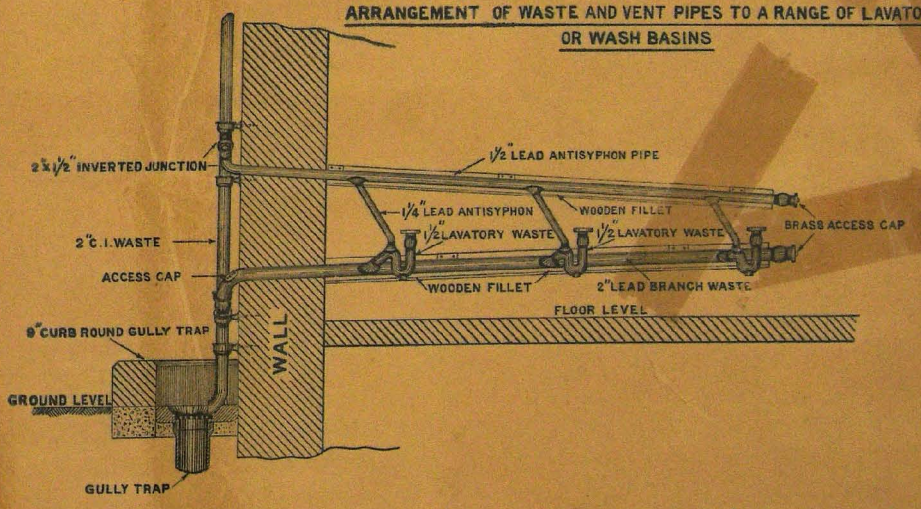
SIDE ELEVATION



FRONT ELEVATION



ARRANGEMENT OF WASTE AND VENT PIPES TO A RANGE OF LAVATORIES OR WASH BASINS

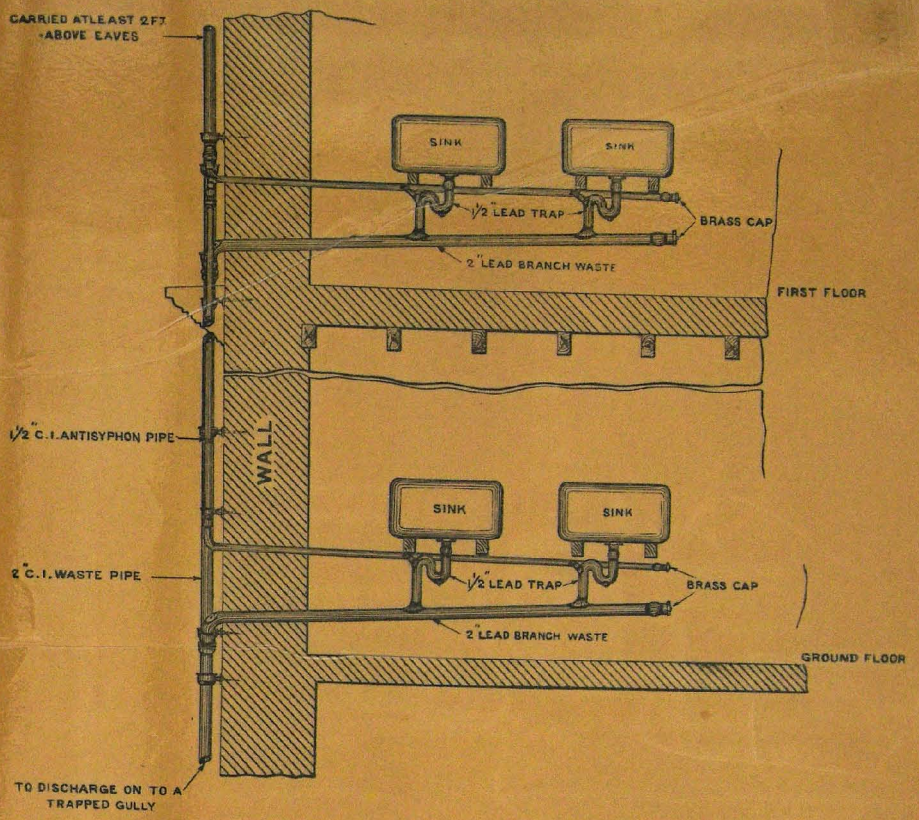


M.A., M. Inst. C. E., M. Am. Soc. C. E., Etc.,
Special Engineer,
Corporation of Madras.

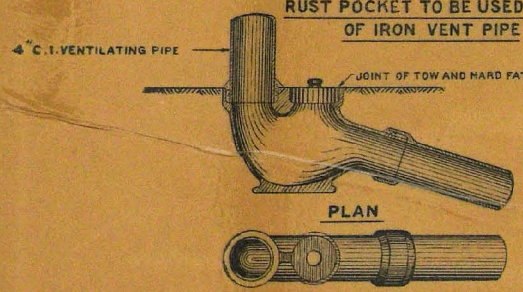
PLATE XXXI.

FIRST-CLASS HOUSE DRAINAGE.

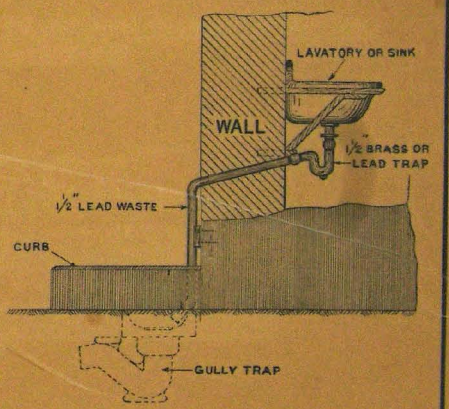
ARRANGEMENT OF WASTE AND VENT PIPES TO TWO RANGES OF SINKS ON SEPARATE FLOORS



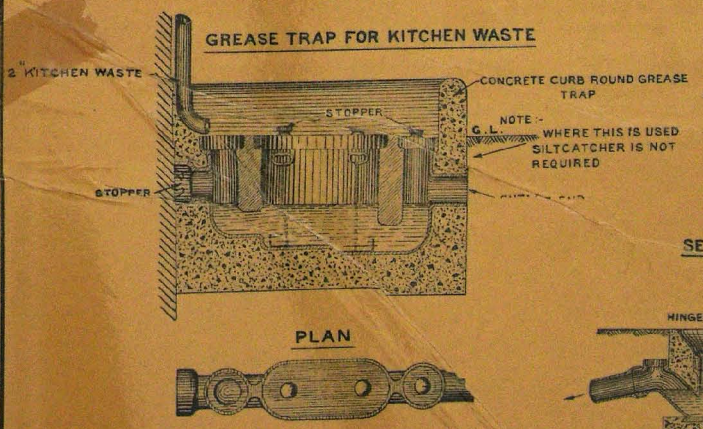
RUST POCKET TO BE USED AT THE FOOT OF IRON VENT PIPE



LAVATORY OR SINK WASTE ON GROUND FLOOR

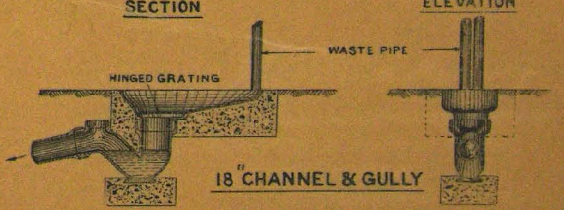


GREASE TRAP FOR KITCHEN WASTE



SECTION

ELEVATION



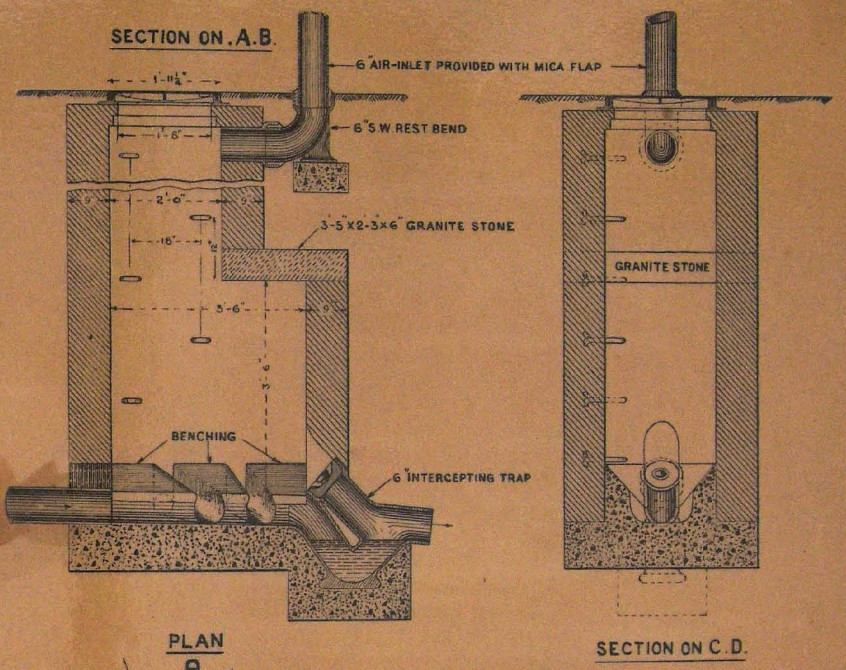
18" CHANNEL & GULLY

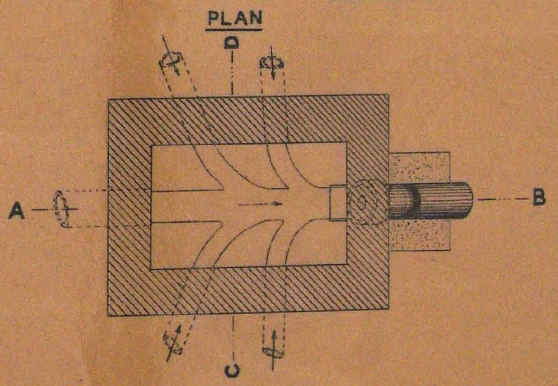
J. W. Madeley.

M.A., M. Inst. C. E., M. Am. Soc. C.E., Etc.,
Special Engineer,
Corporation of Madras.

PLATE XXXII.

FIRST-CLASS HOUSE DRAINAGE.





MANHOLE PLAN AND SECTIONS

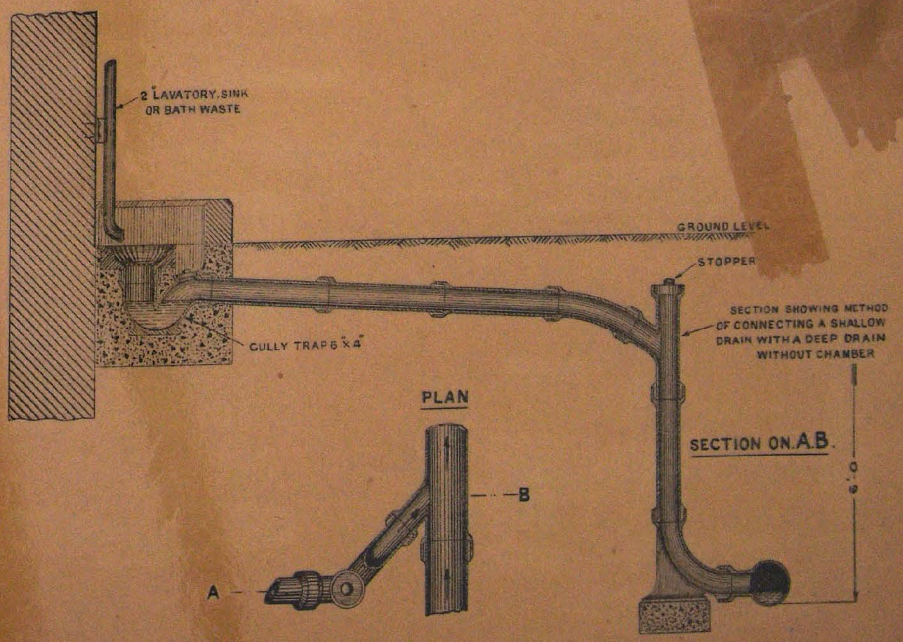


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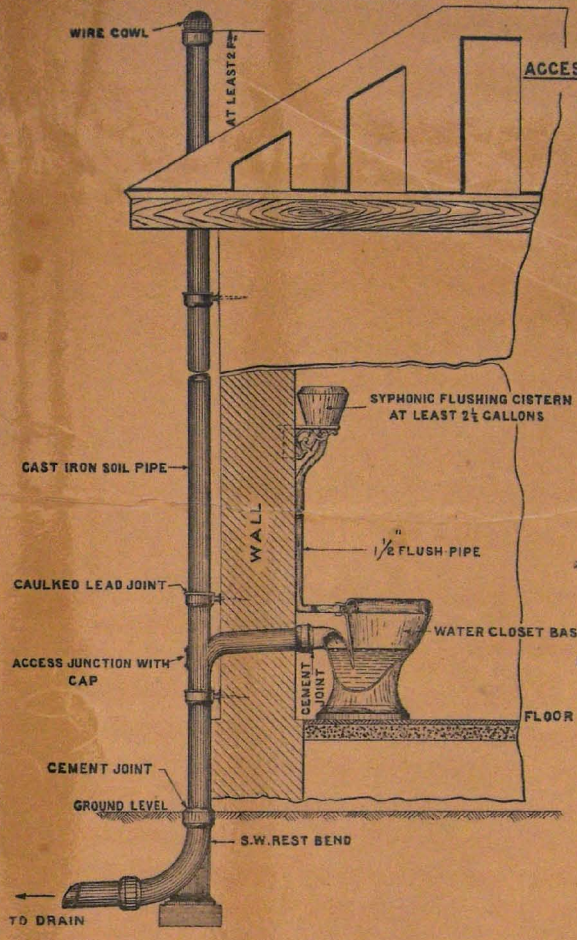
PLATE XXV.

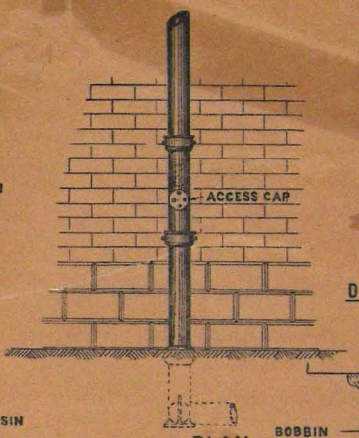
FIRST-CLASS HOUSE DRAINAGE.

ARRANGEMENTS OF CAST IRON SOIL PIPE WITH ACCESS JUNCTION & CONNECTION TO SINGLE WATER CLOSET BED-PAN-SINK SLOP-SINK

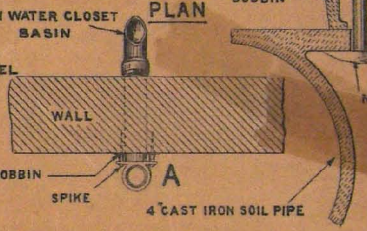
SIDE ELEVATION



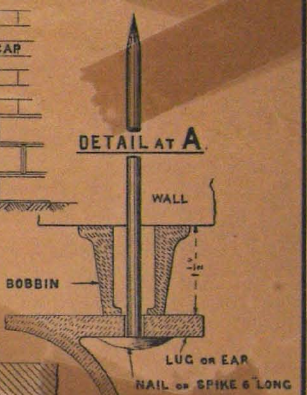
FRONT ELEVATION



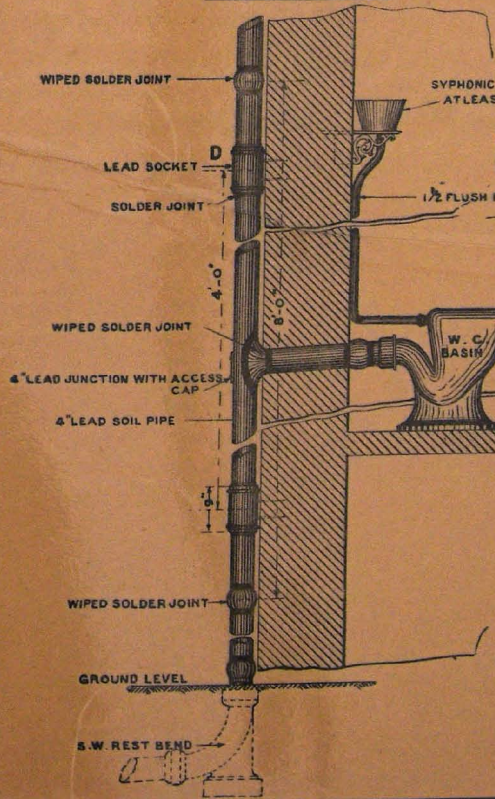
PLAN



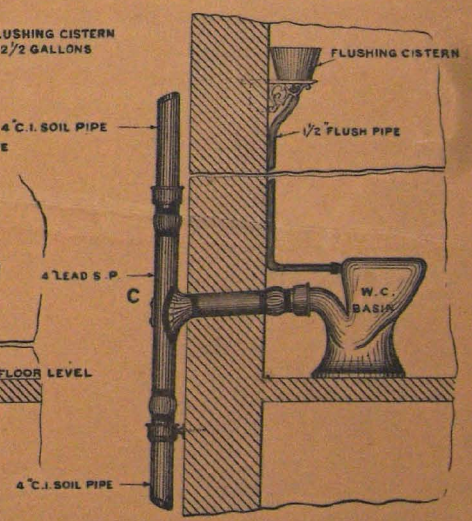
DETAIL AT A



ELEVATION OF LEAD SOIL PIPE AND LEAD BRANCH FOR WATER CLOSET



ELEVATION OF LEAD JUNCTION WITH ACCESS CAP ON CAST IRON SOIL PIPE



J. W. Madeley.

M. A., M. Inst. C. E., M. Am. Soc. C. E., Etc.,
Special Engineer,
Corporation of Madras.

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FIRST-CLASS HOUSE DRAINAGE.

PLATE XXVI.

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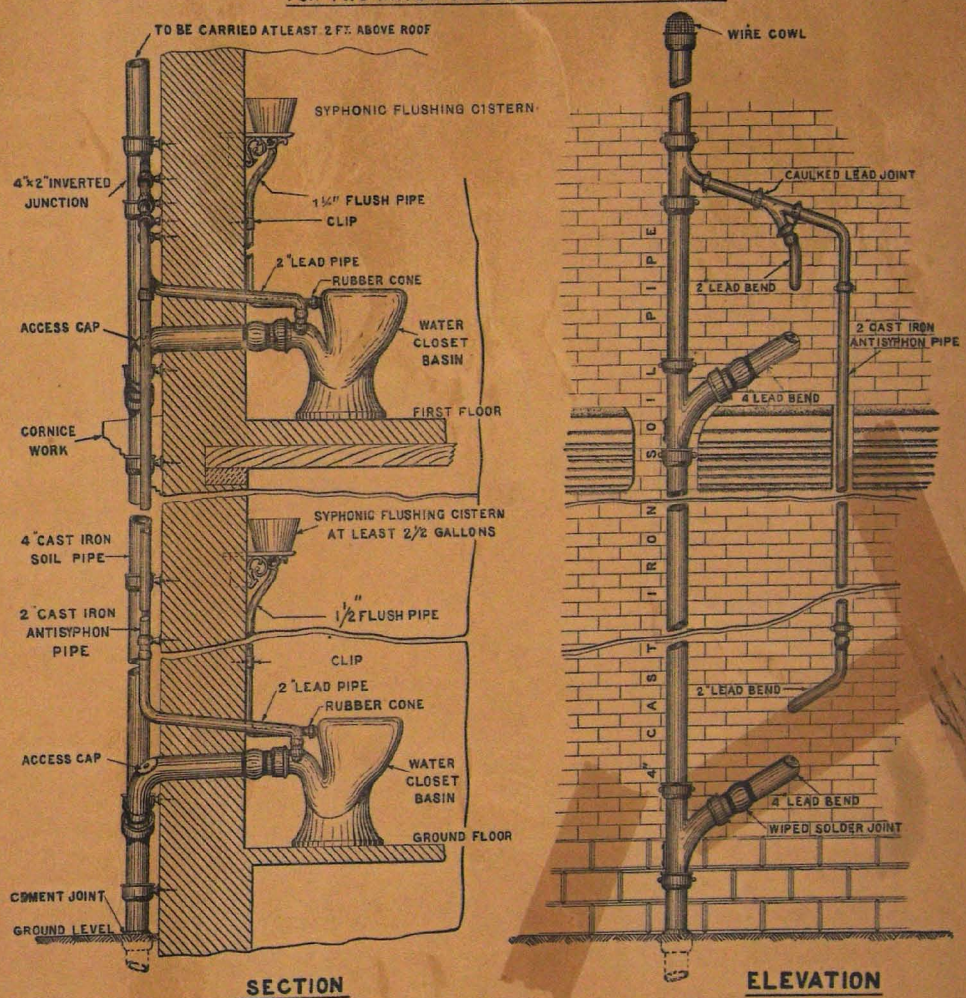
ELEVATIONS SHOWING ARRANGEMENT OF SOIL AND VENT PIPES FOR TWO WATER CLOSETS ON SEPARATE FLOORS



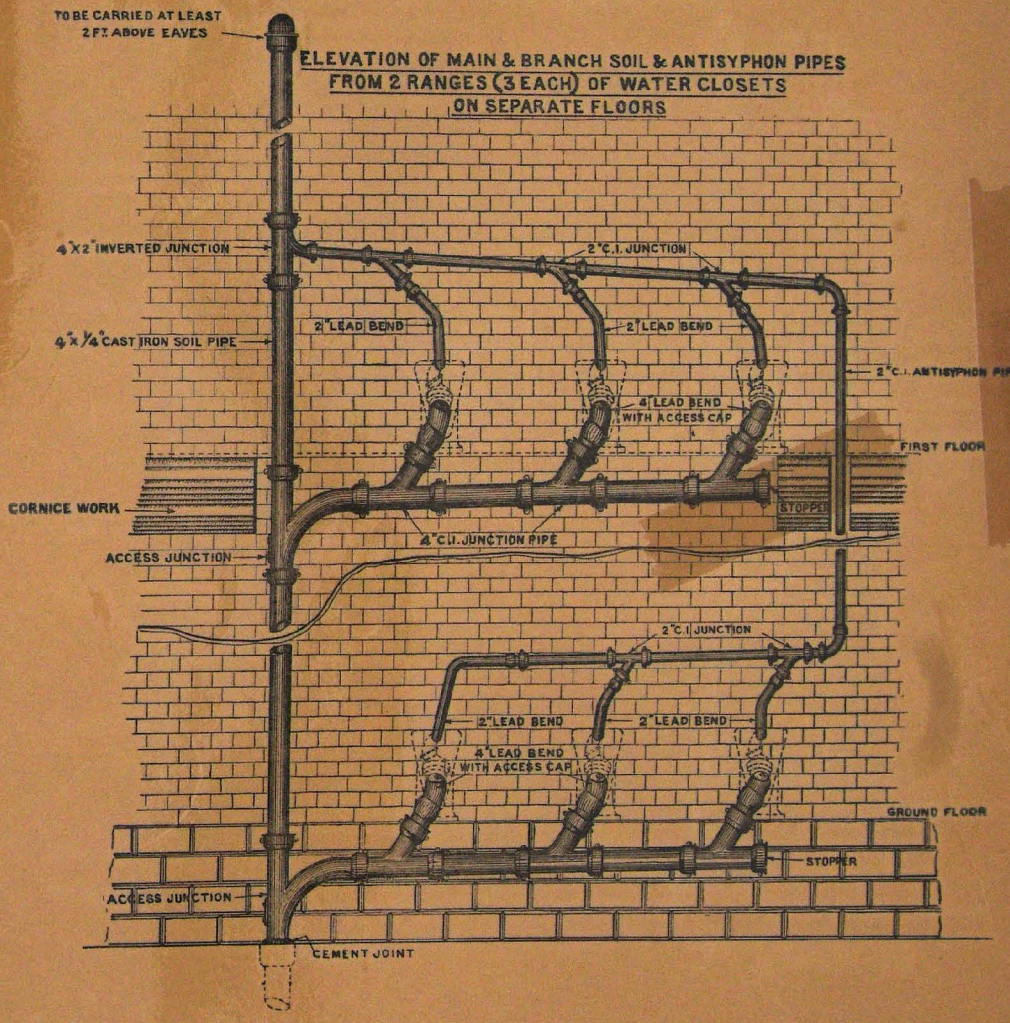
J. Chadderton,

M.A., M. Inst. C. E., M. Am. Soc. C. E., Etc.,
Special Engineer,
Corporation of Madras.

2/40 G1

PLATE XXVII.

FIRST-CLASS HOUSE DRAINAGE.



M A., M. Inst. C. E., M. Am. Soc. C. E., Etc.,
Special Engineer,
Corporation of Madras.

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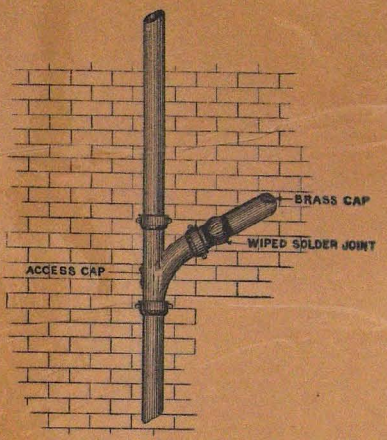
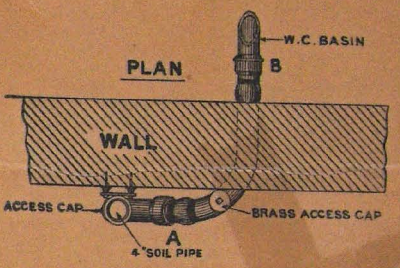
PLATE XXVIII.

FIRST-CLASS HOUSE DRAINAGE—*Details.*

PLAN AND ELEVATION SHOWING ARRANGEMENT OF C.I. SOIL PIPE WITH LEAD BEND CONNECTION FROM SOIL PIPE TO WATER CLOSET

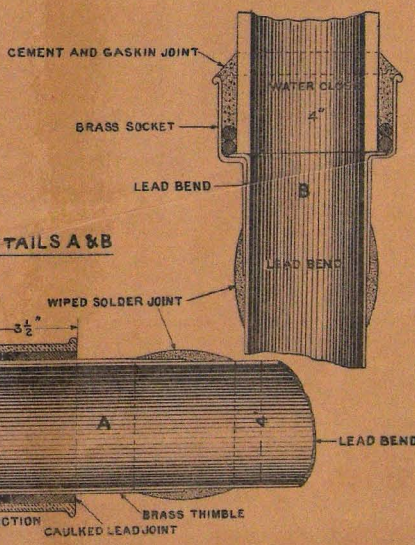
FRONT ELEVATION

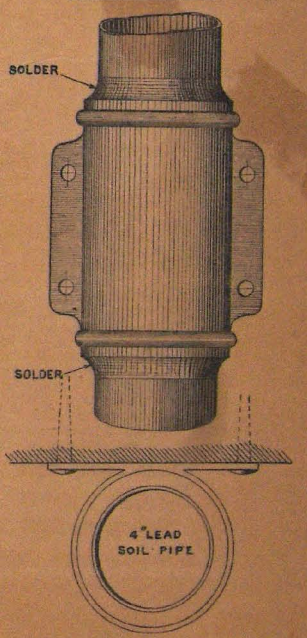




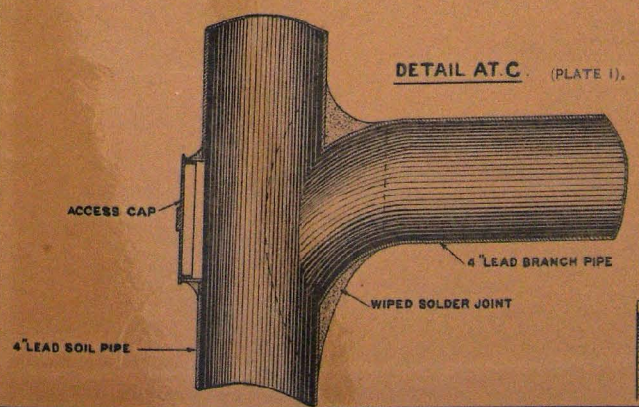
ELEVATION SHOWING SOCKET METHOD OF FIXING LEAD SOIL-PIPE TO WALL

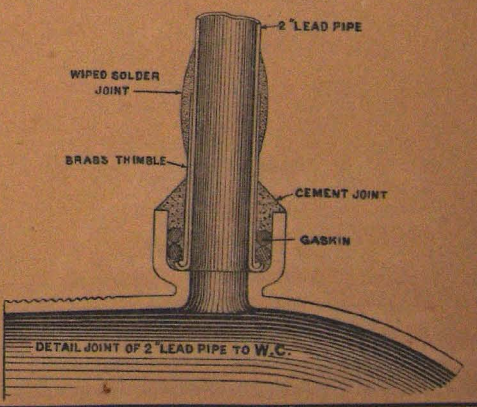
DETAIL AT D (PLATE I)





DETAIL AT C. (PLATE I).





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APPENDIX No. 2.

ESTIMATED POPULATIONS AND DISCHARGES DEALT WITH BY THE PROPOSED NEW DRAINAGE SYSTEM, IN 1940 AND 1961.

Appendix

Estimated Populations and Discharges dealt

	DRAINAGE AREA.	Estimated Population, 1940.	Maximum rate of discharge at $66\frac{2}{3}$ gallons per head per day.	
			Gallons per day.	Cub. ft. per min.
1	North Mylapore	9,720	648,000	72
2	South Mylapore	16,748	1,116,533	124
3	Edward Elliott's Road	11,664	777,600	86
4	Ice House Road	47,464	3,164,267	352
5	Napier Park	77,680	5,178,667	576
6	Graeme's Road	17,589	1,172,600	130
7	Lang's Garden	26,461	1,764,066	196
8	Purasawakkam	106,722	7,114,800	790
9	Law College	42,737	2,849,133	317
10	Rayapuram	108,565	7,237,667	804
11	Tondiarpet A, B & C	72,403	4,826,866	536
12	Tondiarpet D	1,312	87,467	10
13	,, E	4,584	305,600	34
	TOTAL ...	543,649	36,243,266	4,027

No. 2.

with by the Proposed New Drainage System, 1940.

MAXIMUM FLOWS IN

Existing C. I. Main (Mylapore to Kuppam Road) and proposed 3 feet Gravitation Brick Sewer.	Relaid 36-inch C. I. Main from Rayapuram.	4 ft. 6 ins. Brick Sewer in Surianarayana Chetty Street.	Proposed 33 ins. —36 ins. C. I. Main and 4 ft. 6 ins. Gravitation Main from Purasawakkam to Kuppam Road.	4 ft. 6 ins. Brick Sewer in Kuppam Road.	5 ft. 6 ins. Brick Sewer in Surianarayana Chetty Street ending at Farm Pumping Station.	Open Channel along Sewage Farm.
Cub. ft. per min.	Cub. ft. per min.	Cub. ft. per min.	Cub. ft. per min.	Cub. ft. per min.	Cub. ft. per min.	Cub. ft. per min.
1,210	...	...	...	2,326	3,983	4,027
...	..	...	1,116			
...	1,121	1,657	...	...		
...	...					
...	...	...	...	...	...	
1,210	1,121	1,657	1,116	2,326	3,983	4,027

Appendix

Estimated Populations and Discharges dealt

	DRAINAGE AREA.	Estimated Population, 1961.	Maximum rate of discharge at 66⅔ gallons per head per day.	
			Gallons per day.	Cub. ft. per min.
1	North Mylapore	11,666	777,733	86
2	South Mylapore	19,949	1,329,933	148
3	Edward Elliott's Road	14,417	961,133	107
4	Ice House Road	53,129	3,541,933	393
5	Napier Park	82,439	5,495,933	611
6	Graeme's Road	21,483	1,432,200	159
7	Lang's Garden	29,644	1,976,266	220
8	Purasawakkam	124,805	8,320,333	924
9	Law College	45,188	3,012,533	335
10	Rayapuram	113,847	7,589,800	843
11	Tondiarpet A, B & C	80,047	5,336,466	594
12	Tondiarpet D	1,531	102,066	11
13	„ E	5,371	358,066	39
	TOTAL ...	603,516	40,234,305	4,470

No. 2.

with by the Proposed New Drainage System, 1961.

MAXIMUM FLOWS IN						
Existing C. I. Main (Mylapore to Kuppam Road) and proposed 3 feet Gravitation Brick Sewer.	Relaid 36-inch C. I. Main from Rayapuram.	4 ft. 6 ins. Brick Sewer in Surianarayana Chetty Street.	Proposed 33 ins. —36 ins. C. I. Main and 4 ft. 6 ins. Gravitation Main from Purasawakkum to Kuppam Road.	4 ft. 6 ins. Brick Sewer in Kuppam Road.	5 ft. 6 ins. Brick Sewer in Surianarayana Chetty Street ending at Farm Pumping Station.	Open Channel along Sewage Farm.
Cub. ft. per min.	Cub. ft. per min.	Cub. ft. per min.	Cub. ft. per min.	Cub. ft. per min.	Cub. ft. per min.	Cub. ft. per min.
1,345	...	...	...	2,648	...	
...	...	...	1,303		4,420	
...	1,178	1,772	...	...		4,470
...	...					
...	...	...	...	...	...	
1,345	1,178	1,772	1,303	2,648	4,420	4,470

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APPENDIX No. 3.

TABLES SHOWING HOW POPULATIONS OF DRAINAGE AREAS HAVE BEEN ESTIMATED.

Appendix No. 3.

Tables showing how Populations of Drainage Areas have been estimated.

MYLAPORE AREA.

Circle No.	Percentage of Population in Drainage Area.	Estimated Population in			Length of Sewer.	Average Length of Sewer per Head.	
		1911.	1940.	1961.		1911.	1961.
			North Area.		Feet.	Feet.	Feet.
7	90%	4,088	5,109	6,132	10,500	2·56	1·10
8	100%	3,689	4,611	5,534	10,600	2·87	1·70
		7,777	9,720	11,666	21,100	**2·71**	**1·80**
			South Area.				
10	100%	4,034	4,841	5,648	19,250	4·77	3·40
11	100%	6,226	7,471	8,716	22,500	3·61	2·50
13	80%	3,285	4,436	5,585	15,300	4·65	2·70
		13,545	16,748	19,949	57,050	**4·21**	**2·90**

EDWARD ELLIOT'S ROAD AREA.

Circle No.	Percentage of Population in Drainage Area.	Estimated Population in			Length of Sewer.	Average Length of Sewer per Head.	
		1911.	1940.	1961.		1911.	1961.
					Feet.	Feet.	Feet.
1	40%	2,080	2,705	3,329	5,300	2·54	1·50
2	30%	1,405	1,827	2,248	3,700	2·63	1·60
3	30%	1,338	1,673	2,008	4,300	3·21	2·10
5	10%	436	577	719	2,400	5·50	3·30
6	100%	3,195	4,314	5,432	12,700	3·97	2·30
7	10%	454	568	681	2,200	4·84	3·20
		8,908	11,664	14,417	30,600	**3·43**	**2·10**

Note.—Figures in heavy type denote average lengths in feet per head for the areas concerned.

Appendix No. 3.

Tables showing how Populations of Drainage Areas have been estimated

ICE HOUSE ROAD AREA.

Circle No.	Percentage of Population in Drainage Area.	Estimated Population in			Length of Sewer.	Average Length of Sewer per Head.	
		1911.	1940.	1961.		1911.	1961.
					Feet.	Feet.	Feet.
26	100%	4,591	5,279	5,968	9,400	2·04	1·50
27	100%	4,946	5,440	5,934	11,700	2·38	1·90
28	100%	3,271	3,353	3,434	5,150	1·57	1·50
29	100%	3,990	4,090	4,190	8,000	2·00	1·80
30	50%	2,149	2,257	2,364	4,905	2·28	2·00
31	100%	4,934	5,304	5,674	11,950	2·42	2·00
32	50%	1,528	1,566	1,604	4,300	2·81	2·60
33	50%	1,883	2,024	2,165	3,900	2·07	1·80
34	35%	1,449	1,739	2,029	10,250	7·07	5·00
1	50%	2,601	3,381	4,161	7,750	2·97	1·80
2	70%	3,279	4,264	5,248	9,400	2·86	1·70
3	70%	3,124	3,905	4,686	6,900	2·28	1·40
4	100%	4,051	4,862	5,672	12,350	3·04	2·20
		41,796	47,464	53,129	105,955	**2·53**	**2·00**

NAPIER PARK AREA.

14	100%	4,719	4,837	4,955	10,450	2·21	2·0
15	100%	8,132	8,335	8,538	13,500	1·66	1·60
16	100%	4,977	5,101	5,225	8,750	1·75	1·70
17	100%	6,614	7,440	8,267	11,500	1·73	1·40
18	100%	2,323	2,381	2,439	6,100	2·62	2·50
19	100%	4,055	4,156	4,257	9,470	2·33	2·20
35	5%	138	159	180	4,000	28·98	22·20
23	100%	5,113	5,368	5,624	10,950	2·14	1·90
20	100%	3,829	3,924	4,020	7,430	1·94	1·80
21	100%	4,606	4,721	4,836	7,540	1·63	1·60
22	100%	7,789	8,763	9,716	14,000	1·79	1·40
24	100%	8,537	9,390	10,244	17,000	1·99	1·70
25	100%	4,440	4,773	5,106	6,750	1·52	1·30
34	50%	2,071	2,485	2,899	11,570	5·58	4·00
30	50%	2,149	2,257	2,364	4,905	2·27	2·00
32	50%	1,528	1,566	1,604	4,300	2·79	2·60
33	50%	1,883	2,024	2,165	3,900	2·07	1·80
		72,903	77,680	82,439	152,115	**2·08**	**1·80**

Note.—Figures in heavy type denote average lengths in feet per head for the areas concerned.

Appendix No. 3. 250

Showing how Population of Drainage Areas have been estimated—*(contd.)*.

GRAEME'S ROAD AREA.

Circle No.	Percentage of Population in Drainage Area.	Estimated Population in			Length of Sewer.	Average Length of Sewer per Head.	
		1911.	1940.	1961.		1911.	1961.
					Feet.	Feet.	Feet.
36	100%	3,960	5,346	6,732	20,000	5·05	3·00
37	98%	4,227	5,495	6,762	16,790	3·97	2·50
35	95%	2,625	3,018	3,412	9,500	3·61	2·80
34	15%	621	745	870	5,450	8·77	6·30
1	10%	520	676	832	4,400	8·46	5·30
5	40%	1,742	2,309	2,875	13,500	7·74	4·70
		13,695	17,589	21,483	69,640	**5·08**	**3·20**

LANG'S GARDENS AREA.

54	100%	4,624	5,317	6,011	18,950	4·09	3·10
55	100%	2,021	2,425	2,829	15,700	7·76	5·50
56	100%	3,831	4,789	5,747	25,700	6·70	4·50
57	100%	6,680	7,348	8,016	18,100	2·70	2·30
58	100%	6,123	6,582	7,041	9,800	1·60	1·40
		23,279	26,461	29,644	88,250	**3·79**	**3·00**

Note.—Figures in heavy type denote average lengths in feet per head for the areas concerned.

Appendix No. 3.

Tables showing how Populations of Drainage Areas have been estimated—*(contd.)*.

PURASAWAKKAM AREA.

Circle No.	Percentage of Population in Drainage Area.	Estimated Population in			Length of Sewer.	Average Length of Sewer per head.	
		1911.	1940.	1961.		1911.	1961.
					Feet.	Feet.	Feet.
41	100%	3,725	4,283	4,842	12,580	3·37	2·60
42	100%	3,917	4,896	5,875	16,430	4·19	2·80
43	100%	6,832	8,540	10,248	21,330	3·12	2·10
44	100%	3,160	3,402	3,644	8,220	2·60	2·30
45	100%	4,730	4,966	5,203	13,770	2·91	2·60
46	100%	6,842	7,697	8,552	12,190	1·78	1·40
47	100%	9,010	9,685	10,361	17,230	1·91	1·70
48	100%	5,729	7,161	8,593	8,863	1·54	1·30
49	100%	3,031	3,788	4,546	18,500	6·10	4·00
50	100%	9,773	11,238	12,704	17,974	1·83	1·40
51	100%	3,365	3,533	3,701	5,030	1·52	1·40
52	100%	7,143	7,321	7,500	19,230	2·69	2·60
53	100%	4,151	4,254	4,358	11,450	2·75	2·60
60	95%	5,662	9,059	12,457	18,440	3·25	1·50
62	70%	4,923	7,386	9,847	16,430	3·33	1·70
63	100%	5,969	8,655	11,342	8,410	1·40	0·70
39	20%	684	858	1,032	5,800	8·47	5·60
		88,646	106,722	124,805	231,877	**2·61**	**1·90**

LAW COLLEGE AREA.

72	2%	99	103	108	500	5·05	4·60
73	90%	4,129	4,335	5,047	9,550	2·31	1·90
74	75%	6,421	6,742	7,063	10,750	1·67	1·50
75	100%	2,788	2,927	3,067	10,500	3·76	3·40
76	100%	6,188	6,497	6,807	6,800	1·09	1·00
77	100%	5,330	5,596	5,863	8,250	1·54	1·40
78	100%	5,170	5,428	5,687	12,300	2·37	2·10
79	100%	771	809	848	3,500	4·53	4·10
80	100%	2,764	2,876	2,989	10,900	3·97	3·60
81	40%	2,632	2,738	2,843	5,000	1·89	1·70
82	60%	3,997	4,158	4,318	11,150	2·78	2·60
83	10%	508	528	548	3,000	5·90	5·50
		40,797	42,737	45,188	92,200	**2·26**	**2·04**

Note.—Figures in heavy type denote average lengths in feet per head for the areas concerned.

Appendix No. 3.

Tables showing how Populations of Drainage Areas have been estimated—*(contd.)*.

RAYAPURAM AREA.

Circle No.	Percentage of Population in Drainage Area.	Estimated Population in			Length of Sewer.	Average Length of Sewer per Head.	
		1911.	1940.	1961.		1911.	1961.
					Feet.	Feet.	Feet.
64	100%	6,869	7,041	7,213	12,900	1·87	1·80
65	100%	4,839	4,960	5,081	8,900	1·83	1·80
66	100%	4,796	4,915	5,035	7,150	1·49	1·40
67	100%	7,344	8,078	8,812	12,950	1·76	1·40
68	100%	5,484	5,621	5,758	9,700	1·76	1·70
69	100%	7,728	8,307	8,886	15,450	1·99	1·80
70	100%	4,467	4,690	4,914	5,900	1·32	1·20
71	100%	6,036	6,337	6,639	10,400	1·72	1·60
72	98%	4,835	5,076	5,319	9,150	1·89	1·80
81	60%	3,948	4,107	4,267	9,250	2·34	2·10
82	40%	2,664	2,772	2,879	8,000	3·00	2·80
83	90%	4,568	4,750	4,933	16,500	3·61	3·30
84	100%	5,791	6,023	6,255	14,150	2·44	2·20
85	100%	5,706	5,934	6,162	11,550	2·02	1·90
86	100%	6,477	6,736	6,995	13,200	2·03	1·90
87	100%	6,643	6,908	7,174	12,650	1·90	1·80
88	100%	4,393	4,568	4,744	9,750	2·21	2·00
89	100%	3,501	3,641	3,781	18,050	5·12	4·80
90	100%	2,458	2,949	3,441	5,700	2·31	1·70
91	5%	270	337	400	2,000	7·40	5·00
94	60%	746	895	1,045	1,000	1·34	1·0
98	40%	1,418	1,489	1,560	3,900	2·75	2·50
95	10%	180	184	200	1,200	6·66	6·00
74	25%	2,140	2,247	2,354	3,100	1·44	1·30
		103,301	108,565	113,847	222,500	**2·15**	**2·00**

Note.—Figures in heavy type denote average lengths in feet per head for the areas concerned.

Appendix No. 3.

Tables showing how Populations of Drainage Areas have been estimated—*(contd.)*.

TONDIARPET (A, B & C COMBINED) AREA.

Circle No.	Percentage of in Population Drainage Area.	Estimated Population in			Length of Sewer.	Average Length of Sewer per head.	
		1911.	1940.	1961.		1911.	1961.
					Feet.	Feet.	Feet.
91	95%	5,125	6,407	7,693	6,250	1·21	0·80
92	100%	3,713	3,898	4,084	11,200	3·01	2·70
93	70%	1,305	1,500	1,696	4,700	3·60	2·70
94	40%	498	597	696	1,100	2·20	1·60
95	90%	1,621	1,662	1,692	9,700	5·98	5·80
96	100%	3,813	3,908	4,003	13,200	3·46	3·20
97	100%	3,653	3,744	3,838	9,600	2·62	2·50
98	60%	2,127	2,233	2,341	5,300	2·49	2·30
99	100%	2,850	3,562	4,275	10,200	3·57	2·30
100	100%	3,314	3,728	4,142	7,500	2·26	1·80
101	100%	1,696	1,908	2,120	2,700	1·59	1·20
102	100%	2,068	2,325	2,582	6,200	2·99	2·40
103	100%	4,864	5,472	6,080	12,300	2·52	2·00
104	100%	3,579	4,026	4,474	8,000	2·23	1·70
105	100%	4,344	4,887	5,430	12,000	2·76	2·20
106	100%	3,811	4,287	4,764	10,350	2·71	2·20
107	100%	3,574	4,021	4,468	8,700	2·46	1·90
108	100%	2,671	3,472	4,272	16,000	5·98	3·70
109	100%	3,493	3,667	3,842	14,900	4·26	3·60
110	100%	2,873	3,160	3,447	5,700	1·98	1·30
111	80%	3,668	3,939	4,108	11,950	3·23	2·90
		64,660	72,403	80,047	187,550	**2·90**	**2·30**
		Tondiarpet D Area.					
113	70%	1,094	1,312	1,531	18,200	**16·63**	**11·80**
		Tondiarpet E Area.					
111	20%	917	985	1,052	11,300	12·32	10·70
112	100%	2,879	3,599	4,319	27,700	9·62	6·40
		3,796	4,584	5,371	39,000	**10·27**	**7.20**

Note.—Figures in heavy type denote average lengths in feet per head for the areas concerned.

Appendix No. 3.

Summary of estimated Populations of 1911, 1940 and 1961 and lengths of Sewer per head for the Proposed Drainage Areas.

	Drainage Area.	Estimated Population in			Average length of Sewer per head for 1911.
		1911.	1940.	1961.	
					Feet.
1	North Mylapore	7,777	9,720	11,666	2·71
2	South Mylapore	13,545	16,748	19,949	4·21
3	Edward Elliott's Road	8,908	11,664	14,417	3·43
4	Ice House Road	41,796	47,464	53,129	2·53
5	Napier Park	72,903	77,680	82,439	2·08
6	Graeme's Road...	13,695	17,589	21,483	5·08
7	Lang's Gardens	23,279	26,461	29,644	3·79
8	Purasawakkam...	88,646	106,722	124,805	2·61
9	Law College	40,797	42,737	45,188	2·26
10	Rayapuram	103,301	108,565	113,847	2·15
11	Tondiarpet (A, B & C combined) ...	64,660	72,403	80,047	2·90
12	Tondiarpet D	1,094	1,312	1,531	16·63
13	„ E	3,796	4,584	5,371	10·27
	TOTAL ...	484,197	543,649	603,516	**2·71**

Population and Lengths of Street served by sewers at flattest ordinary proposed gradients flowing half full for various linear densities of Population.

Diameter of Pipe.	S. W. D. flattest Gradient.	Population served.	Length of Street served at following rates.						
			1½ ft. per head.	1¾ ft. per head.	2 ft. per head.	2¼ ft. per head.	2½ ft. per head.	2¾ ft. per head.	3 ft. per head.
6 inches.	1 in 135	2,100	3,150	3,700	4,200	4,700	5,250	5,800	6,300
9 „	1 „ 230	4,700	7,050	8,220	9,400	10,570	11,750	12,900	14,100
12 „	1 „ 340	8,500	12,750	14,870	17,000	19,120	21,250	23,370	25,500
15 „	1 „ 460	13,250	19,870	23,190	26,500	29,810	33,120	36,440	39,750
18 „	1 „ 580	19,150	28,720	33,510	38,300	43,080	47,870	52,660	57,450
21 „	1 „ 720	26,000	39,000	45,500	52,000	58,500	65,000	71,500	78,000
24 „	1 „ 860	33,900	50,850	59,370	67,800	76,270	84,750	93,220	101,700
27 „	1 „ 1,000	43,000	64,500	75,200	86,000	96,750	107,500	118,250	129,000
30 „	1 „ 1,150	53,100	79,650	92,920	106,200	119,470	132,750	146,020	159,300

Note.—The figure in heavy type denotes the average length in feet per head for all the drainage areas.

APPENDIX No. 4.

POPULATION AND DENSITY OF POPULATION OF CIRCLES AND DIVISIONS FOR 1911, 1940 AND 1961.

Appendix

Estimated Population for Circles for 1940 and 1961.

New Division No.	Circle No.	Population, 1901 Census.	Population, 1911 Census.	Estimated Population in 1940.	Estimated Percentage increase for 50 years, 1911 to 1961.	Estimated increase for 50 years, 1911 to 1961.	Estimated Population in 1961.	Area in Acres.	Density, per acre, 1911.	Estimated Density, per acre, 1940.	Estimated Density, per acre, 1961.
19	1	4,287	5,202	6,762	60%	3,121	8,323	231	23	29	36
	2	4,118	4,685	6,091	60%	2,811	7,496	180	26	34	42
	3	4,313	4,463	5,578	50%	2,231	6,694	142	32	39	47
	4	3,581	4,051	4,862	40%	1,621	5,672	139	29	35	41
	5	4,184	4,356	5,772	65%	2,832	7,188	385	11	15	19
	6	2,644	3,195	4,314	70%	2,237	5,432	188	17	23	29
	7	3,859	4,542	5,677	50%	2,271	6,813	151	30	37	45
	8	3,128	3,689	4,611	50%	1,845	5,534	141	26	33	40
		30,114	34,183	43,667	**55%**	18,969	53,152	1,557	**22**	**28**	**34**
20	9	3,384	3,444	4,475	60%	2,067	5,511	563	6	8	10
	10	3,382	4,034	4,841	40%	1,614	5,648	100	40	48	56
	11	5,061	6,226	7,471	40%	2,490	8,716	81	77	92	107
	12	1,508	2,449	3,551	90%	2,204	4,653	688	4	6	7
	13	3,463	4,107	5,545	70%	2,875	6,982	479	9	12	15
		16,798	20,260	25,883	**55%**	11,250	31,510	1,911	**11**	**14**	**17**
16	14	5,041	4,719	4,837	5%	236	4,955	18	262	268	275
	15	8,000	8,132	8,335	5%	406	8,538	33	247	253	259
	16	4,989	4,977	5,101	5%	248	5,225	26	191	196	201
	17	6,202	6,614	7,440	25%	1,653	8,267	70	94	106	118
	18	2,392	2,323	2,381	5%	116	2,439	26	89	92	94
		26,624	26,765	28,094	**10%**	2,659	29,424	173	**155**	**163**	**170**
17	19	4,076	4,055	4,156	5%	202	4,257	38	107	109	112
	20	3,746	3,829	3,924	5%	191	4,020	26	147	151	155
	21	4,404	4,606	4,721	5%	230	4,836	20	230	236	242
	22	6,956	7,789	8,763	25%	1,947	9,736	61	129	144	159
	23	4,974	5,113	5,368	10%	511	5,624	129	40	42	44
	24	7,533	8,537	9,390	20%	1,707	10,244	50	171	188	205
	25	4,090	4,440	4,773	15%	666	5,106	27	165	177	189
		35,779	38,369	41,095	**14%**	5,454	43,823	351	**109**	**117**	**125**

Note.—Heavy type figures in total columns denote averages for the divisions.

No. 4.

Estimated Population for Circles for 1940 and 1961—*(contd.)*.

New Division No.	Circle No.	Population, 1901 Census.	Population, 1911 Census.	Estimated Population in 1940.	Estimated Percentage increase for 50 years, 1911 to 1961.	Estimated increase for 50 years, 1911 to 1961.	Estimated Population in 1961.	Area in Acres.	Density, per acre, 1911.	Estimated Density, per acre, 1940.	Estimated Density, per acre, 1961.
18	26	4,560	4,591	5,279	30%	1,377	5,968	71	65	74	84
	27	4,295	4,946	5,440	20%	988	5,934	34	143	154	175
	28	3,176	3,271	3,353	5%	163	3,434	16	204	210	215
	29	4,052	3,990	4,090	5%	200	4,190	20	200	205	210
	30	4,275	4,299	4,514	10%	430	4,729	28	154	162	169
	31	4,725	4,934	5,304	15%	740	5,674	45	109	117	126
	32	2,791	3,056	3,132	5%	152	3,208	23	133	136	139
	33	3,577	3,767	4,049	15%	564	4,331	52	73	78	83
		31,451	32,854	35,161	**14%**	4,614	37,468	289	**114**	**122**	**130**
15	34	3,731	4,142	4,970	40%	1,656	5,798	170	24	29	34
	35	3,549	2,763	3,177	30%	829	3,592	126	22	25	29
	36	2,927	3,960	5,346	70%	2,772	6,732	375	11	14	18
	37	4,090	4,314	5,607	60%	2,586	6,900	331	13	17	21
		14,297	15,179	19,100	**51%**	7,843	23,022	1,002	**15**	**19**	**23**
14	38	2,935	3,617	4,539	51%	1,844	5,461	395	9	11	14
	39	3,077	3,421	4,293	51%	1,744	5,165	524	7	8	10
	40	3,534	4,682	5,825	51%	2,287	6,969	315	15	18	22
		9,546	11,720	14,657	**51%**	5,875	17,595	1,234	**10**	**12**	**14**
11	41	3,388	3,725	4,283	30%	1,117	4,842	45	83	95	108
	42	3,188	3,917	4,896	50%	1,958	5,875	82	48	60	72
	43	6,161	6,832	8,540	50%	3,416	10,248	83	82	102	123
	44	3,108	3,160	3,402	15%	484	3,644	35	90	97	104
	45	4,322	4,730	4,966	10%	473	5,203	45	105	110	116
	46	5,615	6,842	7,697	25%	1,710	8,552	55	124	139	155
	47	7,902	9,010	9,685	15%	1,351	10,361	70	129	138	148
	51	3,422	3,365	3,533	10%	336	3,701	40	84	88	92
		37,106	41,581	47,002	**26%**	10,845	52,426	455	**91**	**103**	**115**

Note.—Heavy type figures in total columns denote averages for the divisions.

Appendix

Estimated Population for Circles for 1940 and 1961—*(contd.)*

New Division No.	Circle No.	Population, 1901 Census.	Population, 1911 Census.	Estimated Population in 1940.	Estimated Percentage increase for 50 years, 1911 to 1961.	Estimated increase for 50 years, 1911 to 1961.	Estimated Population in 1961.	Area in Acres.	Density, per acre, 1911.	Estimated Density, per acre, 1940.	Estimated Density, per acre, 1961.
12	48	5,328	5,729	7,161	50%	2,864	8,593	100	57	71	86
	49	2,887	3,031	3,788	50%	1,515	4,546	161	19	23	28
	50	9,308	9,773	11,238	30%	2,931	12,704	91	107	124	140
	52	5,604	7,143	7,321	5%	357	7,500	79	90	92	95
	53	3,833	4,151	4,254	5%	207	4,358	23	180	185	189
		26,960	29,827	33,762	**26%**	7,874	37,701	454	**66**	**74**	**83**
13	54	4,190	4,624	5,317	30%	1,387	6,011	84	55	63	72
	55	2,503	2,021	2,425	40%	808	2,829	119	17	21	24
	56	3,318	3,831	4,789	50%	1,916	5,747	266	14	18	22
	57	6,409	6,680	7,348	20%	1,336	8,016	56	119	131	143
	58	5,534	6,123	6,582	15%	918	7,041	31	197	212	227
		21,954	23,279	26,461	**26%**	6,365	29,644	556	**42**	**47**	**52**
10	59	1,362	1,707	3,070	160%	2,727	4,434	48	36	64	92
	60	5,065	5,960	9,536	120%	7,152	13,112	52	115	184	252
	61	3,761	3,970	6,550	130%	5,161	9,131	255	16	26	36
	62	5,211	7,034	10,551	100%	7,034	14,068	306	23	34	46
	63	5,888	5,969	8,655	90%	5,373	11,342	10	597	865	1,134
		21,287	24,640	38,362	**110%**	27,447	52,087	671	**36**	**57**	**77**
7	64	7,503	6,869	7,041	5%	344	7,213	62	111	114	116
	65	4,786	4,839	4,960	5%	242	5,081	19	255	261	267
	66	4,950	4,796	4,915	5%	239	5,035	20	242	247	252
	67	7,103	7,344	8,078	20%	1,468	8,812	73	100	110	121
	68	6,125	5,484	5,621	5%	274	5,758	24	228	233	239
	69	7,936	7,728	8,307	15%	1,158	8,886	35	228	241	254
		38,403	37,060	38,922	**10%**	3,725	40,785	233	**159**	**167**	**175**

Note.—Heavy type figures in total columns denote averages for the divisions.

No. 4.

Estimated Population for Circles for 1940 and 1961—*(contd).*

New Division No.	Circle No.	Population, 1901 Census.	Population, 1911 Census.	Estimated Population in 1940.	Estimated Percentage increase for 50 years, 1911 to 1961.	Estimated increase for 50 years, 1911 to 1961.	Estimated Population in 1961.	Area in Acres.	Density, per acre, 1911.	Estimated Density, per acre, 1940.	Estimated Density, per acre, 1961.
8	70	5,244	4,467	4,690	10%	447	4,914	21	213	223	234
	71	5,392	6,036	6,337	10%	603	6,639	14	421	447	474
	72	4,922	4,934	5,180	10%	493	5,427	30	164	172	181
	73	4,354	4,588	4,817	10%	459	5,047	31	148	127	107
	74	8,756	8,562	8,990	10%	856	9,418	28	305	320	336
		28,668	28,587	30,014	**10%**	2,858	31,445	124	**230**	**242**	**253**
9	75	3,346	2,788	2,927	10%	279	3,067	22	127	133	139
	76	5,757	6,188	6,497	10%	619	6,807	22	281	295	309
	77	5,355	5,330	5,596	10%	533	5,863	22	242	254	267
	78	5,807	5,170	5,428	10%	517	5,687	30	172	181	190
	79	2,039	771	809	10%	77	848	40	19	20	21
		22,304	20,247	21,257	**10%**	2,025	22,272	136	**148**	**156**	**164**
6	80	3,255	2,764	2,876	8%	225	2,989	33	84	87	91
	81	7,449	6,581	6,845	8%	528	7,109	38	173	180	187
	84	7,635	5,791	6,023	8%	464	6,255	31	187	194	201
	86	6,823	6,477	6,736	8%	518	6,995	33	196	204	212
		25,162	21,613	22,480	**8%**	1,735	23,348	135	**160**	**166**	**172**
5	82	5,537	6,665	6,931	8%	532	7,197	61	109	113	118
	85	5,865	5,706	5,934	8%	456	6,162	27	211	219	228
	87	6,155	6,643	6,908	8%	531	7,174	40	166	172	179
		17,557	19,014	19,773	**8%**	1,519	20,533	128	**148**	**154**	**160**
4	83	7,126	5,076	5,278	8%	405	5,481	47	108	112	117
	88	6,289	4,393	4,568	8%	351	4,744	21	209	217	226
	89	3,713	3,501	3,641	8%	280	3,781	44	80	83	86
		17,128	12,970	13,487	**8%**	1,036	14,006	112	**115**	**120**	**125**

NOTE.—Heavy type figures in total columns denote averages for the divisions.

Appendix No. 4.

Estimated Population for Circles for 1940 and 1961—*(contd)*

New Division No.	Circle No.	Population, 1901 Census.	Population, 1911 Census.	Estimated Population in 1940.	Estimated Percentage increase for 50 years, 1911 to 1961.	Estimated increase for 50 years, 1911 to 1961.	Estimated Population in 1961.	Area in Acres.	Density, per acre, 1911.	Estimated Density, per acre, 1940.	Estimated Density, per acre, 1961.
3	90	2,488	2,458	2,949	40%	983	3,441	63	39	47	55
	91	6,006	5,395	6,744	50%	2,698	8,093	139	39	48	58
	92	3,683	3,713	3,898	10%	371	4,084	28	133	139	146
	93	2,309	1,865	2,144	30%	559	2,424	102	18	22	26
	113	1,968	1,563	1,875	40%	625	2,188	375	4	4	4
		16,454	14,994	17,610	**35%**	5,236	20,230	707	**21**	**25**	**29**
2	94	623	1,244	1,492	40%	497	1,741	78	16	19	22
	98	4,115	3,546	3,723	10%	355	3,901	72	49	51	54
	99	3,353	2,850	3,562	50%	1,425	4,275	36	79	99	119
	100	3,203	3,314	3,728	25%	828	4,142	19	174	196	218
	101	2,436	1,696	1,908	25%	424	2,120	11	154	173	193
	102	2,397	2,068	2,325	25%	514	2,582	13	159	251	344
	103	5,569	4,864	5,472	25%	1,216	6,080	38	128	144	160
	104	4,348	3,579	4,026	25%	895	4,474	13	275	309	344
	105	5,167	4,344	4,887	25%	1,086	5,430	21	207	233	259
	106	3,959	3,811	4,287	25%	953	4,764	44	87	97	108
	107	3,757	3,574	4,021	25%	894	4,468	32	112	126	140
	108	2,924	2,671	3,472	60%	1,602	4,273	159	17	22	27
	112	4,661	2,879	3,599	50%	1,440	4,319	208	14	17	21
		46,512	40,440	46,502	**30%**	12,129	52,569	744	**54**	**62**	**70**
1	95	2,211	1,802	1,847	5%	90	1,892	23	78	80	82
	96	4,321	3,813	3,908	5%	190	4,003	50	76	78	80
	97	4,214	3,655	3,744	5%	183	3,838	40	91	93	96
	109	3,634	3,493	3,667	10%	349	3,842	59	59	62	65
	110	3,071	2,873	3,160	20%	574	3,447	15	192	211	230
	111	3,739	4,585	4,924	15%	678	5,263	216	21	22	24
		21,190	20,221	21,250	**10%**	2,064	22,285	403	**50**	**52**	**55**

NOTE.—Heavy type figures in total columns denote averages for the divisions

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APPENDIX No. 5.

TABLE SHOWING LENGTHS AND GRADIENTS OF PIPE SEWERS.

	PAGES.
Stoneware Pipe Sewers	...262—265
Cast-iron ,, ,, ...	.. 266—267

Appendix

Table showing Lengths and

DRAINAGE

Size of Pipe.	Gradient 1 in	Mylapore.	Edward Elliott's Road.	Ice House Road.	Napier Park.	Graeme's Road.
						Stoneware
6 inches.	60	4,410	4,023	14,280	5,150	1,770
	65	...	...	...	260	...
	70	520	...	...	3,820	...
	75	...	...	...	325	...
	80	1,440	2,610	2,100	8,140	7,170
	85	...	...	...	1,040	...
	90	...	275	...	3,590	...
	95	...	...	...	...	...
	100	11,275	13,781	15,820	29,600	22,751
	110	...	...	...	990	..
	115	...	...	...	...	...
	120	...	...	...	4,035	...
	125	...	...	...	530	...
	128	...	...	...	...	...
	130	...	...	...	...	...
	135	10,890	4,028	12,020	2,185	7,698
	150	**400** / *360*	...	**250**	**300**	...
	Total ...	29,295	24,717	44,470	59,965	39,389
9 inches.	90	...	...	...	...	...
	100	4,760	2,148	8,790	1,070	4,970
	135	1,810	300	...	...	480
	150	2,600	3,585	1,440	300	2,926
	160	...	...	...	320	...
	165	...	...	...	330	...
	180	...	...	...	180	...
	200	7,670	3,832	5,410	13,600	5,674

Note.—Figures in heavy type denote lengths of new sewers at gradient flatter than ordinary minimum gradient and imum gradients.

No. 5.

Gradients of Pipe Sewers.

AREAS.					
Lang's Gardens.	Purasawakkam.	Law College.	Rayapuram.	Total.	Tondiarpet (North).
Pipe Sewers.					
1,480	17,710	8,602	15,527	72,952	1,420
...	...	390	650	1,300	130
210	...	2,260	2,360	9,170	560
225	...	150	910	1,610	3,500
590	7,320	4,500	18,533	52,403	260
...	...	510	455	2,005	...
...	...	1,505	3,545	8,915	...
...	...	380	760	1,140	...
13,354	31,800	13,648	31,454	183,483	17,990
560	...	995	6,300	8,845	...
...	...	115	230	345	...
240	...	2,675	7,730	14,680	...
..	...	445	250	1,225	...
...	...	...	255	255	...
...	...	260	250	510	...
5,026	45,680	3,860	12,994	104,381	58 50
200	*490*	...	...	**1,150** *850*	...
21,885	103,000	40,295	102,203	465,219	29,710
...	...	480	...	480	...
1,110	11,410	5,079	740	40,077	1,600
...	3,910	...	...	6,500	600
300	4,660	3,640	470	19,921	8,250
...	...	...	..	320	160
...	...	...	...	330	...
...	...	...	...	180	3,000
5,233	10,650	20,524	59,029	131,622	2,480

figures in italics denote lengths of sewers to replace existing sewers where gradients available are flatter than ordinary

Appendix

Table showing Lengths and

Size of Pipe.	Gradient 1 in	DRAINAGE				
		Mylapore.	Edward Elliott's Road.	Ice House Road.	Napier Park.	Graeme's Road.
						Stone ware
9 inches.	220	...	...	...	...	...
	230	27,760	11,433	24,150	9,430	17,404
	250	...	...	...	**910**	...
	260	**140** *1,420*	**2,287**	**6,770**	...	**5,940**
	280	...	...	...	...	...
	Total ...	46,160	23,585	46,560	26,140	37,394
12 inches.	260	...	...	...	...	...
	300	1,730	...	540	1,180	...
	340	5,840	3,703	4,370	2,660	3,100
	380	...	**2,365**	...	...	**4,124**
	420	...	...	...	...	...
	Total ...	7,570	6,068	4,910	3,840	7,224
15 inches.	460	6,710	1,320	1,300	2,870	4,180
	520	...	**745**	...	...	**2,033**
	Total ...	6,710	2,065	1,300	2,870	6,213
18 inches.	400	240	...	...	...	...
	580	1,700	1,670	400	3,910	...
	660	...	...	...	*510*	**1,910**
	Total ...	1,940	1,670	400	4,420	1,910
21 inches.	700	...	...	...	1,675	...
	720	...	1,185	1,530	...	...
	830	...	**5,328**	...	...	**650**
	Total ...	...	6,513	1,530	1,675	650
	Total length of Stone-ware Pipes.	91,675	64,618	99,170	98,910	92,780

Note.—Figures in heavy type denote lengths of new sewers at gradient flatter than ordinary minimum gradient and minimum gradients.

No. 5.

Gradients of Pipe Sewers—(*contd.*).

AREAS.					
Lang's Gardens.	Purasawakkam.	Law College.	Rayapuram.	Total.	Tondiarpet (North).
Pipe Sewer—(*continued*).					
1,546	...	...	220	1,766	...
5,050	47,620	4,030	15,245	162,122	19,970
...	...	...	...	**910**	...
8,474	**7,930** *2,990*	**2,785**	...	**34,326** *4,410*	...
...	..	...	**1,010**	1,010	...
21,713	89,170	36,538	76,714	403,974	36,060
3,429	...	...	...	3,429	...
590	...	...	...	4,040	...
1,230	8,400	2,140	5,835	37,278	10,310
900	**4,780** *710*	**500**	...	**12,669** *710*	...
...	...	...	**1,285**	**1,285**	...
6,149	13,890	2,640	7,120	59,411	10,310
1,185	4,600	930	1,240	24,335	5,240
...	**5,250** *1,230*	...	...	**8,028** *1,230*	**2,200**
1,185	11,080	930	1,240	33,593	7,440
...	...	...	...	240	240
400	2,000	460	...	...	10,540
...	**3,250** *1,000*	...	*1,304*	...	**5,160** *2,814*
400	6,250	460	1,304	18,754	2,980
..	...	..	...	1,675	...
3,360	1,180	975	...	8,230	...
...	*1,410*	**2,280**	*1,830*	**8,258** *3,240*	...
3,360	2,590	3,255	1,830	21,403	...
54,692	225,980	84,118	190,411	1,002,354	56,500

figures in italics denote lengths of sewers to replace existing sewers where gradients available are flatter than ordinary

Appendix

Table showing Lengths and

Size of Pipe.	Gradient 1 in	DRAINAGE				
		Mylapore.	Edward Elliott's Road.	Ice House Road.	Napier Park.	Graeme's Road.
						Cast-iron
24 ins.	860	...	...	840	1,890	...
	1,000	...	...	..	...	...
	1,300	...	...	...	...	...
	Total ...	...	...	840	1,890	...
27 ins.	1,000	...	...	1,280	...	...
	1,500	...	...	...	...	...
	Total ...	...	..	1,280	...	...
30 ins.	1,000	...	...	...	1,890	...
	1,150	...	...	970	...	...
	1,600	...	...	...	...	...
	Total ...	...	...	970	1,890	...
36 ins.	**1,600**	...	...	...	...	...
	Total ...	...	...	...	...	...
	Total length of Cast-iron Pipes ...	...	...	3,090	3,780	...
	Grand Total of Sewer Pipes ...	91,675	64,618	102,260	102,690	92,780

Note.—Figures in heavy type denote lengths of new sewers at gradient flatter than ordinary minimum gradient and minimum gradients.

No. 5.

Gradients of Pipe Sewers—(*contd*).

AREAS.					
Lang's Gardens.	Purasawakkam.	Law College.	Rayapuram.	Total.	Tondiarpet (North).
Pipe Sewers.					
1,600	...	...	...	4,330	...
...	...	...	*1,200*	1,200	...
...	...	...	*780*	780	...
1,600	...	...	1,980	6,310	...
...	...	...	...	1,280	...
...	...	...	*1,520*	1,520	...
...	...	...	1,520	2,800	...
...	...	140	...	2,030	...
...	...	...	...	970	...
...	...	...	*1,160*	1,160	...
...	...	140	1,160	4,160	...
...	...	...	*3,880*	3,880	...
...	...	...	3,880	3,880	...
1,600	...	140	8,540	17,150	...
56,292	225,980	84,258	198,951	1,019,504	...

figures in italics denote lengths of sewers to replace existing sewers where gradients available are flatter than ordinary

APPENDIX No. 6.

Copy of letter dealing with enforcement of connections to Municipal Drains and Installation of Water-closets in Bombay.

20th January, 1913.

FROM

P. R. CADELL, ESQ., I.C.S.,
Municipal Commissioner
for the City of Bombay.

TO

THE PRESIDENT,
Corporation of Madras.

SIR,

With reference to your letter S. E. No. 2318/12 of the 19th ultimo, regarding the enforcement of (1) connections to sewers and (2) conversion of privies into water-closets, I have the honour to state that the Municipal Commissioner is empowered (1) under Section 231 of the City of Bombay Municipal Act, 1888, to enforce the drainage of undrained premises situate within a hundred feet of a Municipal drain, and (2) under Section 248 (1), with the previous approval of the Standing Committee, to require the owners of premises to substitute water-closet accommodation for privy accommodation. I forward copies of these sections. If these requirements are not complied with the parties are prosecuted in the Police Court under Section 471 of the Municipal Act under which the maximum fine which may be imposed by the Magistrate is fixed at Rs. 50 in each case. For continued offences the parties are again prosecuted under Section 472 and the after-conviction daily fine which may be imposed is Rs. 5. No difficulty has therefore been experienced in compelling fulfilment of Municipal requirements in either of the above cases. The process of converting privies into water-closets has been temporarily suspended pending improvement of the water-supply.

I have the honour to be,
Sir,
Your most obedient servant,
(Signed) P. R. CADELL,
Municipal Commissioner
for the City of Bombay.

APPENDIX No. 7.

Draft By-laws for House Drainage framed under Clauses (9), (10) and (11) of Section 409 of the Madras City Municipal Act, 1904, passed by the Corporation on 16th July, 1912, and sanctioned by Government in G. O. No. 2240 M., dated 26th November, 1912.

1. Every person who intends or is required to lay out, construct, or alter any drains or other works referred to in Clauses (9), (10) and (11) of Section 409 of Act III of 1904 shall comply with the following requirements :—

Notice of intention to construct works.

(1) He shall, before commencing any such work, give the President fifteen days' notice in writing of such intention, and such notice in duplicate shall be delivered at the Municipal Office in the form given in the Appendix of which printed copies with the necessary blanks may be obtained by application at the Municipal Office on payment of three pies.

(2) He shall enter upon such notice his full name and address, and shall state the division, street and assessment number of the premises upon which such works are intended to be executed, and all the particulars required in the printed form of notice.

Deposit of plans and sections.

(3) He shall deposit, together with such notice, plans and sections in duplicate clearly and indelibly made on a durable material and drawn to a scale of not less than one inch to every sixteen feet, and the horizontal scale of the sections shall be the same as the scale of the plans, and he shall show thereon the whole of the intended new drains with their proposed sizes and gradients in figures, and the levels of the ground surface and depths of the proposed drains, and the position of every building, gully, soil pipe, waste pipe, ventilating pipe, water-closet, bath, lavatory, urinal, latrine, sink, trap, or other appliance on the premises connected or proposed to be connected with any drains, and the position and course of all surface drains and the names of the streets adjoining the premises and the scale to which the plan is drawn ; and the proposed new drains and appliances shall be shown in red and the existing buildings, drains, and appliances in black, or otherwise distinctively indicated by different colours.

He shall also deposit cross sections with dimensions shown in figures to a scale of not less than one inch to one foot of all open drains showing the ground level and the curbs or other means already existing or proposed for exclusion of storm water and silt.

(4) On application by any party the Corporation will provide him with the necessary plans and estimates on payment of a sum equal to 5 per cent. of the estimates subject to a minimum charge to be fixed from time to time by the Standing Committee. Such

application shall be accompanied by a deposit of Rs. 2, which will be credited to the abovementioned charge for plans and estimates.

(5) The schedule of rate at which work will be done by the Corporation in the event of any party not having carried out the work himself, will be attached to the application form.

Approval or disapproval of plans.

2. (1) Within thirty days after the deposit of the notice and plans and sections required by By-law 1, the President shall signify in writing to the person who gave such notice whether such plans and sections are approved or otherwise, and may direct such person to make any alterations or improvements which appear to be necessary or desirable, and such person shall alter the plans and sections accordingly.

(2) When the plans and sections have been approved, one copy thereof shall be returned to such person and one copy shall be retained by the President.

One copy of the plans and sections approved by the President shall be kept at the site of the work at all times when the work is in progress and such plans and sections shall be available at all times for the inspection of the President or of any officer authorized by him in that behalf.

Reservation.

(3) Such person may then proceed with the work, excepting such portions thereof as may be reserved by the President for final connection with any drain vested in the Corporation; provided that if the work is not commenced within three months from the date of the notice of approval of such plans, such approval shall be deemed to be cancelled.

Unlawful commencement of work.

(4) Every person who without first obtaining the consent of the President in writing commences any such work before the plans and sections have been approved shall be liable to a penalty as specified in By-law 8 below.

Notice of covering up portion of work.

3. Every person who constructs or alters any drains or other works shall, before proceeding to cover up any portion of any foundations, drains, or appliances connected with drainage, give the President notice in writing that such foundations, drains, or appliances are ready for inspection, and specify the date and hour on which he will proceed to cover up such foundations, drains, or appliances, and such notice shall be in a form, of which printed copies with the necessary blanks may be obtained gratis on application at the Municipal Office, and he shall cause such notice to be delivered at the Municipal Office at least seven clear days before the date specified as aforesaid therein.

Notice of completion.

4. (1) Every person who constructs or alters any drains or other works shall give the President notice in writing specifying the date and hour at which such drains or works will be ready for final inspection and, if required, for connection with any existing

drain, and such notice shall be in a form, of which printed copies with the necessary blanks may be obtained gratis on application at the Municipal Office, and he shall cause such notice to be delivered at the Municipal Office at least seven clear days before the date specified as aforesaid therein.

Deposit of money.

(2) He shall deposit such sum of money as the President may demand to meet the cost of the connection with any drain vested in the Corporation before such connection is commenced.

5. (1) Whenever the President refuses to approve the plans and sections under By-law 2 (1) he shall state specifically the grounds for such refusal and the applicant may appeal to the Standing Committee against such refusal. The decision of the Standing Committee shall be final.

If the Standing Committee reject any such appeal, they shall by written order specifically state the grounds for such rejection.

(2) If within the period prescribed in By-law 2 (1) the President has neither given nor refused his approval of the plans and sections, the Standing Committee shall be bound, on the written request of the applicant, to determine by written order immediately on the expiration of such period, whether such approval should be given or not.

(3) If the Standing Committee do not, within fifteen days from the receipt of such written request determine whether such approval should be given or not, such approval shall be deemed to have been given and the applicant may proceed to execute the works, but not so as to contravene any of the provisions of the Madras City Municipal Act, 1904, or any rules or by-laws made thereunder.

Certificate of drainage.

6. (1) No connection of any drain to any drain vested in the Corporation shall be made until the whole of the first-mentioned drain and appliances connected therewith shall have been duly certified in writing by the President as complying with all requirements of the Corporation.

Connection with Public drain

(2) Such connection shall in any case be made only by duly authorised officers of the Corporation.

Inspection.

7. Every person by or for whom any drain or other work connected therewith is laid out, constructed, fixed or altered, shall at all reasonable times afford any authorised officer of the Corporation free access to such drain or work for the purpose of inspection.

Penalties.

8. Every person who shall offend against any of the foregoing by-laws shall be liable for every such offence to a penalty not exceeding 20 rupees, and in case of a continuing offence to a further penalty not exceeding 10 rupees for each day after written notice to discontinue the offence from the President shall have been duly served upon or delivered to such person.

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